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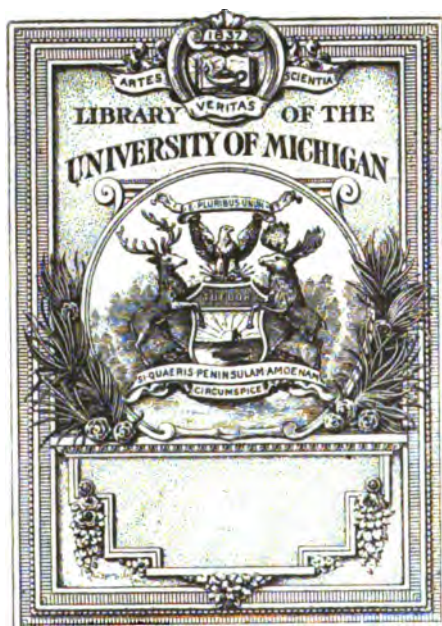
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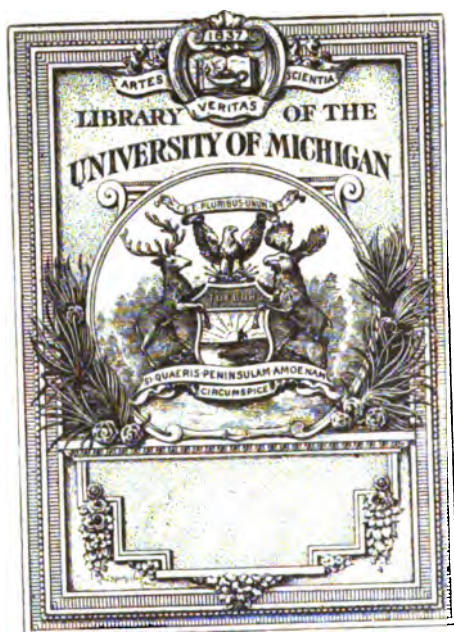
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Issued June 12, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 282.

WILLIAM A. TAYLOR, *Chief of Bureau.*

SEEDS AND PLANTS IMPORTED

DURING THE PERIOD FROM JANUARY 1
TO MARCH 31, 1912:

INVENTORY No. 30; Nos. 32369 to 33278.



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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., December 13, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 282 of the series of this Bureau the accompanying manuscript, entitled "Seeds and Plants Imported during the Period from January 1 to March 31, 1912: Inventory No. 30; Nos. 32369 to 33278."

This manuscript has been submitted by the Agricultural Explorer in Charge of Foreign Seed and Plant Introduction with a view to publication.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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SEEDS AND PLANTS IMPORTED DURING THE PERIOD FROM JANUARY 1 TO MARCH 31, 1912: INVENTORY NO. 30; NOS. 32369 TO 33278.

INTRODUCTORY STATEMENT.

This number of the inventories contains some material of rather unusual interest. It lists part of the collections made by Mr. Frank N. Meyer during his late expedition into Chinese Turkestan, covering particularly the material secured by him from the noted Russian plant breeder, Mr. I. V. Mijurin. It also contains notes regarding some promising forage grasses collected by Mr. C. V. Piper, Agrostologist in Charge of the Office of Forage-Crop Investigations, during his preliminary exploration of India in search of forage grasses particularly adapted to our Southern States, and it also describes a number of Spanish fruit varieties that Mr. Walter T. Swingle, of the Office of Crop Physiology and Breeding Investigations, discovered during his recent trip to Spain, which was made by him in company with Dr. L. Trabut, the veteran plant breeder and horticulturist of Algeria.

In the spring of 1903 Mr. G. Onderdonk, one of the veteran nurserymen of southern Texas, made a trip into Mexico for the purpose of securing varieties of Mexican peaches and apricots which he knew existed in the mountainous regions of the central provinces. A collection of these fruits which he made was planted at San Antonio, Tex., and Nos. 32372 to 32380 of this present inventory are selected seedlings from the trees grown as a result of this expedition. They are said to be late-ripening sorts, resembling somewhat the Honey peach, but are later in ripening. These may prove of unusual value for the southern peach belt.

Of Mr. Meyer's collection the seeds and plants most worthy of notice are as follows: No. 32389, seeds of *Medicago falcata*, which in Mr. Meyer's opinion (and in this he agrees with Prof. N. E. Hansen) is likely to prove of especial value in those situations where the crowns of the plants are damaged by close grazing and by the hoofs of animals; No. 32408 is a variety of *Medicago sativa* selected by Mr. Bogdan at Krassny Koot, one of the best of his hybrids; No. 32416,

the noted Sarepta mustard, which should be called to the attention of mustard growers in this country because of its unusual strength when grown on rich soil in a hot, dry climate; No. 32417, a wild apple from near Sarepta, of possible value as a drought-resistant shrub or medium-sized tree for breeding purposes or for cultivation in the arid Southwest; No. 32424, a hybrid plum (*Prunus spinosa* × *Prunus domestica*), one of Mr. Mijurin's hybrids; No. 32662, a cross between *Amygdalus davidiana* and *Amygdalus nana*, two very hardy types hybridized by Mr. Mijurin and producing a very floriferous, ornamental, hardy form; Nos. 32664 and 32665, two varieties of *Prunus fruticosa* by the same hybridizer; No. 32667, a golden currant by the same breeder from the region of Kozlov, noted for its severe winter climate; No. 32668, a hybrid rose of exceptional hardiness, representing *Rosa spinosissima* and *Rosa rugosa*, by the same hybridizer; Nos. 32669 to 32673, five hybrid plums suited particularly for the colder sections of the country, being hybrids of *Prunus spinosa* and *Prunus domestica*; No. 32674, a remarkable cherry, a variety of *Prunus avium*, originated by Mr. Mijurin and named "Queen of the North," which is considered by Russian horticulturists to be a decided acquisition to hardy fruit trees, growing as it does where other cherries do very poorly; Nos. 32675 and 32676, two of Mr. Mijurin's quinces, which are presumably withstanding a winter temperature of -35° C. (-31° F.) and have succeeded at Kozlov when other varieties have been killed; Nos. 32757 and 32758, two forms of an east Siberian wild plum (*Prunus ussuriensis*) from Souchodole, Russia, the fruits of one of which are said to improve in flavor by being frozen; No. 32762, *Ribes procumbens*, from the Altai Mountains, a species of large-fruited currant which Mr. Meyer recommends for trial in Alaska; No. 32763, *Clematis tangutica*, a yellow-flowered climbing clematis which Mr. Mijurin reports having received from Tibet; No. 32764, a remarkable, new yellow lily, the bulbs of which are reported to weigh as much as 6 pounds apiece, another of Mr. Mijurin's originations; No. 32829, *Ulmus densa*, an ornamental elm capable of standing great heat and a considerable amount of alkali, collected by Mr. Meyer in the oasis of Merv, Russian Turkestan; No. 32831, another species of elm which will probably make a good shade and avenue tree in Texas, Arizona, and New Mexico; Nos. 32832 to 32836, five varieties of apricot from the oasis of Merv; No. 33077, seeds of *Larix sibirica*, from the Altai Mountains, one of the most rapid-growing conifers, capable of withstanding our northern climate; No. 33078, a Siberian spruce (*Picea obovata*); and No. 33079, seeds of the Siberian pine (*Pinus cembra*).

Mr. Piper's collections in India include the following interesting possibilities: No. 32430, *Rytidix granularis*, an annual grass after the

character of the crab-grass and of possible value for the same purposes, from Kirki, India; No. 32436, *Heylandia latebrosa*, from Kirki, a prostrate legume abundant in the Dekkan and said to be a good forage species; No. 32440, *Andropogon caricosus*, one of the hay-producing grasses of central India, considered as excellent forage, from Kirki, India; Nos. 32443 to 32448, 6 species of forage grasses from the Nilgiri Hills (which have a climate similar to that of the coastal region of California), among them being included the most nutritious grasses for hay and pasture known in southern India; Nos. 32491 to 32598, 108 varieties of soy beans from different parts of India; Nos. 32450 and 32453, 2 species of Indian raspberries from the Nilgiri Hills, considered by Mr. Piper as promising for the Southern States; Nos. 32777 and 32778, 2 subspecies of *Cracca villosa* that are being tested in Java as green-manure crops; Nos. 32431 and 32782, *Indigofera tinifolia*, from India, where it is considered one of the very best native pasture legumes, promising for southern California; Nos. 32799 and 32800, two species of wild persimmons from Seharunpur for the persimmon breeders of the Southern States; No. 32808, a new shade tree, *Gmelina arborea*, grown in the upper Ganges Valley and likely to succeed well in southern California; No. 32454, seeds from an unusually good cherimoya, produced by trees descended from the original introduction of this fruit made by Markham into India from Peru; and No. 32429, one of the best pasture grasses in India, *Brachiaria eruciformis*, which forms dense masses of fine stems and appears to be a good seeder.

Dr. Gustav Eisen, of the California Academy of Sciences, during his work for the academy in Spain, called attention to a number of varieties of fruits which have been secured through the British vice consul at Granada. These should recommend themselves especially to Californians as being selected by one familiar with California conditions. Dr. Eisen's studies have convinced him that some of the most valuable California fruit varieties, such as the mission fig, came from the region of Granada and were introduced into California in the early days by the Spanish padres. Among the fruit varieties which he believes are new to California are the Isabella fig (No. 32878), one of the best varieties he has ever tasted; No. 32879, the Jeresiana table grape, which resembles the Verdal but is sweeter and an excellent shipper; the Cuatro Hermanos olive from Canales (No. 32880), which comes from an altitude of 6,000 feet where heavy frosts and snows occur and which may prove an excellent variety for cultivation on the northern limits of olive culture; and No. 32883, the San Martin autumn melon, related to the Casaba but considered superior in quality.

From our correspondents in various parts of the world, particularly from American diplomatic officials and consuls abroad, who have shown an unusual interest in this work, a number of promising plants have been secured: No. 33184, seeds of a remarkable cherimoya weighing 2 pounds 6 ounces, from a tree owned by Mr. Charles F. O'Brien, of Los Angeles, Cal., and probably one of the best varieties now in the United States; Nos. 32470 to 32477, a collection of fig and grape varieties from the island of Chios, off the coast of Greece, by Mr. Pantelides; No. 32480, the Manila maguey, or cantala, from the Philippine Islands, an agave suited for rich, loamy soils containing little lime and for a climate with heavy rainfall, such as is to be found in the island of Porto Rico; No. 32692, a Mexican species of avocado (*Persea mexicana*) from the province of Vera Cruz, through Consul William W. Canada; No. 32705, another of the hard-shelled edible-fruited species of *Strychnos* from Inhamban, Portuguese East Africa; No. 32706, *Abies numidica*, from the Department of Constantine, Algeria, a spruce which grows to 75 feet in height, occurring at 5,000 to 7,000 feet altitude, sent us by the veteran French botanist, Dr. L. Trabut; Nos. 32713 to 32725, 13 varieties of dates from Egypt; Nos. 32845 to 32859, 15 varieties of dates from the various oases of the Sahara, selected by Dr. Trabut; No. 32730, *Nitraria schoberi*, a remarkably alkali-resistant plant from Australia which, according to Dr. J. H. Maiden, bears edible cherrylike fruits; No. 32751, a new variety of prune from Thun, Bern, Switzerland, for trial in the Oregon prune area; No. 32892, a fodder sedge (*Carex physodes*), collected by Mr. W. W. Mackie in the loose sands of the Peshy Kara Kum Desert, where only 4 inches of rain fall; Nos. 32924 to 32929, six species closely related to the cajuput tree of Australia, remarkable because of its ability to grow rapidly on the coast of Florida along the very edge of the salt water; Nos. 33031 to 33047 and 33155 to 33160, a collection of *Cotoneaster*, remarkable doorway shrubs, with attractive red berries in winter and dark-green foliage in summer, which are especially suited as front and back yard shrubs wherever hardy; No. 33093, a broad-leaved evergreen tree from Java, *Dammara alba*, a close relative of the kauri pine of New Zealand, which ought to be peculiarly suited as an avenue tree in Porto Rico, Hawaii, and possibly in Florida; Nos. 33111 to 33118, eight varieties of edible grapes from the western slopes of Mount Lebanon; No. 33166, *Juglans pyriformis*, a walnut said to be native on the slopes of Mount Orizaba, in southern Mexico; Nos. 33205 to 33234, a remarkable collection of Spanish fruit and ornamental trees from the nurseries of Pedro Giraud, of Granada, which were selected by Mr. Swingle during his recent explorations in Spain and which include the azarol (No. 33205), a large-fruited *Crataegus* with a deli-

cious flavor resembling that of the loquat, the Chopo (No. 33206), a striking, rapidly growing species of poplar almost completely devoid of lateral branches and therefore suited for close planting and for pole production, a shipping pear (No. 33209), of good quality, called "Pera de Aragon," a delicious winter apple (No. 33210) called 'Pero Blanco de Ronda,' which ripens in January, and an especially hardy almond (No. 33218), which has flowers that hang down and are thus protected from frost injury and in this way insure its fertility when other varieties lose their crops; Nos. 32708 to 32712 and 33250 to 33255, 11 named varieties of udo from Yokohama, Kyoto, and Tokyo, including early, midsummer, and late varieties, for comparison with the seedling sorts now being experimented with in America; No. 33256, an elephant grass of India, *Typha elephantina*, a species related to our cat-tail flag but having leaves 13 feet long; the yam bean of Jamaica (*Cacara erosa*, No. 33258), which, according to the introducer, ought to supersede the arrowroot in cultivation, being a much larger yielder, and the young pods of which are recommended as "string beans," having absolutely no fiber and being excellent when cooked; No. 33263, a cucumberlike vine from the Director of Agriculture of Zanzibar, bearing fruits weighing 60 pounds, from the seeds of which a culinary oil is expressed by the natives; and No. 33277, seeds of the best strains of winter melons of Valencia, which are famous in Spain, 15,000 tons being exported annually.

A special publication is in process of preparation covering the Egyptian expedition of Mr. Aaron Aaronsohn, which was made in search of the Wahi date and which resulted in the introduction of date suckers of 13 promising varieties (Nos. 32713 to 32725).

As heretofore, the manuscript for this inventory has been prepared by Miss Mary A. Austin, the botanical determinations have been made, the notes on geographic distribution compiled, and the notes on nomenclature prepared by Mr. H. C. Skeels, under the supervision of Mr. Frederick V. Coville, of the Office of Taxonomic and Range Investigations, while Mr. S. C. Stuntz has had general supervision of this inventory, as of all the publications of the Office of Foreign Seed and Plant Introduction.

DAVID FAIRCHILD,

Agricultural Explorer in Charge.

OFFICE OF FOREIGN SEED AND PLANT INTRODUCTION.

Washington, D. C., August 29, 1912.

1

INVENTORY.

32369. PHYTELEPHAS sp.

Ivory-nut palm.

From an island near the west coast of Panama (?). Presented by Mr. M. B. Shantz, Rochester, N. Y. Received January 2, 1912.

"The button industry uses a large amount of vegetable ivory. This is the fruit of a species of palm growing wild in South America, principally in the republics of Ecuador and Colombia. The manufacturers of this city alone use of this material about 15 tons a week, and the question has often arisen as to whether the palm could not be cultivated successfully in Florida or some of the other Southern States." (*Shantz*.)

The plants grown from these seeds will be tested for their suitability to conditions in southern Florida and southern California.

32370. CAPSICUM ANNUUM L.

Red pepper.

From Barcelona, Spain. Presented by Mr. Henry H. Morgan, American consul general. Received January 3, 1912.

"*Pimiento Marrón*." See No. 30084 for previous introduction.

32371. SAPINDUS sp.

Soapberry.

From Brazil. Presented by Mr. Omar E. Mueller, American vice consul, Bahia. Received January 3, 1912.

"These berries have the property of making a lather with water upon being crushed in the hands and are used in the interior in the place of soap. They are the fruit of a tree known here as *Saboneta*, which is indigenous to the dry, arid country of Brazil." (*Mueller*.)

32372 to 32380. AMYGDALUS PERSICA L.

Peach.

From San Antonio, Tex. Grown by Mr. S. H. Hastings, superintendent, San Antonio Experiment Farm. Numbered January 2, 1912.

Mexican seedling peach trees as follows; quoted notes by Mr. Hastings. These were grown from seeds procured by Mr. G. Onderdonk, of Nursery, Tex., while on an exploration trip for the Department of Agriculture in Mexico in 1902-3.

32372. "(No. C 31.) The fruit of this tree closely resembles the Honey peach, which is the best for this section of the South China varieties. In the season of 1910 this tree had much more fruit than the Honey peach, the fruit was more uniform in size, and had a more uniform ripening period. The fruit ripens about the 20th of June, and about a week later than the Honey peach. The tree is a vigorous grower, and Mr. G. Onderdonk recommends it as worthy of propagation."

32373. "(No. E 10.) The fruit of this tree resembles the Honey peach in shape and flavor and is a freestone. The ripening period is about August 18 to 20, or nearly two months later than the Honey variety. Its late-ripening period puts it in the valuable class, although the fruit is not better than the fruit of the Honey peach."

32372 to 32380—Continued.

32374. "(No. I 16.) The fruit of this tree is a large, yellow cling, and has a pleasant, subacid flavor. Ripens about September 3. This peach would be a good shipper. Purely Spanish."

32375. "(No. C 32.) Fruit ripens about August 23 and is a large, light-colored cling. Col. G. B. Brackett considers this peach of good quality and worthy of further trial."

32376. "(No. E 24.) The fruit of this tree ripens about September 1 to 3 and is a freestone. Mr. G. Onderdonk thinks this peach has some South China blood. It has a subacid flavor. Col. G. B. Brackett considers this tree promising."

32377. "(No. H 21.) The fruit ripens about September 7 and is a large greenish cling; quality good. Col. G. B. Brackett thinks it is only suitable for canning."

32378. "(No. H 27.) A medium to large yellow cling, probably purely Spanish. Fruit of medium to good quality, slightly subacid. Ripens about September 15."

32379. "(No. A 16.) Distinctly a South China peach, resembling the Honey peach in all respects, except that it ripens about a month later. Ripening period about July 25."

32380. "(No. D 9.) The fruit of this tree resembles the fruit of the South China type and from indications appears to be a cross between the Spanish and the South China types. It is a freestone and the flavor is good. Ripens about August 10."

32381. LUCUMA sp.

From Mexico. Presented by Mr. Clarence A. Miller, American consul, Tampico. Received January 5, 1912.

"*Zapota Manti*. This fruit is said to be edible, but not especially palatable. Although the supply is not large this fruit sells in the market at the comparatively low price of 5 cents Mexican each." (Miller.)

32382. BROMELIA PINGVIN L.**Pinguin.**

From Tampico, Mexico. Presented by Mr. Clarence A. Miller, American consul. Received January 5, 1912.

"Wild pineapple, or *Huapillo*. This plant is very prolific in this section. In many places it covers thousands of acres, making a thick jungle. The plant propagates from the seed and by starting suckers from the root or trunk. It flourishes in the lowlands or in the highlands. The plant is drowned out or destroyed if the land is flooded for a number of days.

"The leaves contain a fine quality of fiber. The fruit is used by the natives as a vermifuge. The plant itself is said to contain valuable chemical properties.

"These specimens were obtained from Mr. Alexander Smith, of Tampico." (Miller.)

Distribution.—In Panama and the West Indies, and from Colombia to Guiana in the northern part of South America.

32385. MANIHOT sp.**Maniçoba rubber.**

From Brazil, South America. Purchased from Charles W. Jacob & Allison, New York, N. Y. Received January 6, 1912.

32386. PINUS TECOTE Cham. and Schlecht. Okote pine.

From Mexico. Presented by Dr. C. A. Purpus, Zacuapam, Huatusco, Vera Cruz, Mexico. Received January 2, 1912.

"From Esperanza, Puebla. 2,700 to 2,800 meters [8,850 to 9,180 feet] altitude."

Distribution.—Mexico; from San Luis Potosi, where it rises to an elevation of 8,000 feet, southward to the region of Orizaba.

32387 to 32389.

From Siberia. Received through Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry. Received January 6, 1911.

Seeds of the following:

32387. FESTUCA sp.**Fescue.**

From Omsk, Siberia.

"(No. 1629a, July 19, 1911.) A grass said to be native to the steppe country of western Siberia; much grown for hay. Possesses the desirable quality of not sprouting when once plowed under, in case the land is needed for wheat culture. To be tested in the semiarid northwestern sections of the United States." (Meyer.)

32388. TRITICUM DURUM Desf.**Wheat.**

From Chistunka, southwestern Siberia.

"(No. 1630a, September 9, 1911.) A hard-kerneled summer wheat, called *Bjela-turka*, meaning White Turkish. It is much grown throughout western Siberia on account of its resistance to drought and its early-ripening qualities.

"Winter wheats can not be grown successfully in western Siberia, as the winters are too cold and often have very little snow, so at present all wheats raised are summer wheats." (Meyer.)

32389. MEDICAGO FALCATA L.

From western Siberia.

"(No. 1634a, July 18 and October 4, 1911.) The *sholteek*, as this wild alfalfa is generally called in western Siberia, occurs over the greater part of Eurasia, being found in the Himalayas as low down as the thirtieth degree of latitude, near Yakutsk, and in Norway between the sixtieth and seventieth parallels. There is a very great amount of variation to be observed in the wild plant; some forms grow up to from 5 to 6 feet and may be fairly erect, while others reach a height of a few inches only and are often prostrate in habit. The more prostrate forms lend themselves excellently for naturalization purposes on dry pasture grounds, while the erect varieties may be cultivated for forage purposes in sections of the United States where the ordinary alfalfa gets winter killed. The present habits of this *sholteek* indicate that possibly a great amount of selection and breeding may have to be done before ideal types will have been evolved, but the many excellent qualities this plant possesses, viz, the eagerness with which all sorts of domestic animals devour it, its apparently great nutritive capacities, especially for milk cows, its remarkable resistance to drought, to close grazing, and to adverse conditions in general, all seem to make it well worth while to spend some extra efforts on improvement. The roots of this *sholteek* also possess the capacity of producing new plants whenever cut off or when exposed to the air on account of the soil having been washed away. This characteristic is of great value in pasture grounds, where the crowns are easily damaged by the close grazing and by the hoofs of the animals trampling over them. The soil best suited to this *Medicago* seems to be a blackish, well-drained

32387 to 32389—Continued.

earth, but one also finds that it grows luxuriantly in pebbly banks and in dry cliffs composed of sandy loam. This seed should be tested especially for naturalization purposes in pasture grounds in the semiarid belt of northwestern United States." (*Meyer.*)

32390. RHUS LANCEA L. f.**Karree.**

From Pretoria, Union of South Africa. Presented by Mr. J. Burt Davy, Government agrostologist and botanist, Department of Agriculture. Received January 3, 1912.

"The karree-boom of the southwestern Transvaal and adjacent Bechuanaland. It is a valuable hardwood tree for regions of limited rainfall (10 to 15 inches in summer). The fruits are edible. The tree can be grown from poles, as in the case of willows." (*Davy.*)

Distribution.—Found in the Uitenhage and Albany districts of Cape Colony.

32391. VACCINIUM VITIS-IDAEA L.**Cowberry.**

From Norrland, Sweden. Presented by Dr. V. Wittrock, director, Botanic Gardens, Albano, Stockholm, Sweden. Received January 6, 1912.

Seeds.

32392 to 32396.

From Salisbury, Rhodesia. Presented by Mr. H. Godfrey Mundy, agriculturist and botanist, Department of Agriculture. Received January 6, 1912.

Seeds of the following; quoted notes by Mr. Mundy:

32392. CITRULLUS VULGARIS Schrad.**Watermelon.**

"Kafir melon. *Marjorta.*"

This seed shows great variation.

32393. LAGENARIA VULGARIS Ser.**Calabash.**

"Large bottle."

32394. UAPACA SANSIBARICA Pax.**Mahobohobo.**

"Tree having edible fruit and good light timber."

32395. PARINARI MOBOLA Oliver.**Mola.**

"M'hatsa tree. Edible fruit, and timber of some value."

Distribution.—The Batoka Highlands, Angola, and the Mozambique district of southern tropical Africa.

32396. WIDDRINGTONIA WHYTEI Rendle.**Mlanje cypress.**

"The only conifer indigenous to Melssetter district, southern Rhodesia. The tree occurs on the eastern escarpment at an elevation of 6,000 to 7,000 feet."

For description see No. 28690.

32397 to 32398. CITRUS DECUMANA (L.) Murr.**Pomelo.**

From China. Presented by Mr. John M. Nixon, New York, N. Y. Received January 9, 1912.

"These pomelo seeds were sent me by a missionary and are of the white and pink variety of the celebrated Amoy product. The fruit is about the size and shape of our shaddock but without its dryness and bitter taste." (*Nixon.*)

32397. White variety.

32398. Pink variety.

32399. CHAETOCHELOA COSTATA (Roxb.) Skeels.

(*Panicum costatum* Roxburgh 1832, Flora Indica, vol. 1, p. 312.)

The seeds of this grass received from India were identified as *Panicum costatum* Roxburgh, but as it is more closely related to the type of the genus *Chaetochloa* it is here placed in that genus.

Chaetochloa costata was described by Roxburgh from cultivated plants received from Mauritius, where it is common in fields and woods. It is also generally introduced throughout the Tropics of both hemispheres.

From Sibpur, near Calcutta, India. Presented by Maj. A. T. Gage, superintendent, Royal Botanic Garden. Received January 9, 1912.

32400. PERSEA AMERICANA Miller.**Avocado.**

From Orange, Cal. Presented by Mr. C. P. Taft. Received January 10, 1912.

"Fruit absolutely seedless but very small, 3 to 5 inches in length and $\frac{1}{4}$ to 1 inch in diameter. Of possible use in breeding experiments. (Peter Bisset.)

32401 to 32403.

From Central America. Presented by Prof. A. S. Hitchcock, of the Bureau of Plant Industry. Received January 12, 1912.

Seeds of the following; quoted notes by Prof. Hitchcock:

32401. SALVIA sp.

"*Chian*.—Obtained on the market at Punta Arenas, Costa Rica. It is used there in the preparation of a refreshing drink. It was purchased at a drug store by an American physician and by him given to me. I was unable to ascertain the source of the supply, but apparently it is a product of the country."

32402. CHRYSOBALANUS ICACO L.**Iceaco.**

"From San Salvador, Salvador. A common fruit sold in the markets and by street venders. Various colors, especially a yellow and a purple variety."

"Shrub 2 meters [6½ feet] high, found on dry beaches; known as '*Cocoa-plum*.' Fruits about the size of a plum, used for preserves." (Cook and Collins, *Economic Plants of Porto Rico*, p. 114.)

Distribution.—From Acapulco in southern Mexico southeastward through Central America and tropical America, in the West Indies, and in western tropical Africa.

32403. PASSIFLORA LIGULARIS Juss.**Passion fruit.**

"From Santa Ana, Salvador. Commonly sold on the streets. The leathery covering is broken and the seeds with the containing pulp are sucked out."

32404. SOLANUM NIGRUM L.**Nightshade.**

From Kew, England. Procured from the Herbaceous Botanical Garden at Kew, by Prof. William R. Lazenby, Ohio State University, Columbus, Ohio. Received August 31, 1911. Numbered January 13, 1912.

"Plant very dwarf; spreading in habit." (Lazenby.)

32405 to 32424.

From Russia. Received through Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry, January 11 and 12, 1912.

Seeds of the following; quoted notes by Mr. Meyer:

32405 to 32424—Continued.

32405. TRITICUM AESTIVUM L.

Wheat.

From Krassny Koot, Samara Government, Russia.

"(No. 1707a, November 20, 1911.) Variety *graecum*. A variety of soft summer wheat, called *Khivinskata*, coming originally from dry and hot Khiva, Russian Turkestan. This grain at Krassny Koot, however, was received from a firm in Germany named Dreifus. This wheat produces a flour especially suitable for biscuit making and may be found valuable in America for this purpose." (Meyer.)

32406. AGROPYRON CRISTATUM (L.) Beauv.

From near Sarepta, Saratov Government, Russia.

"(No. 1708a, November 28, 1911.) A form of this very promising fodder grass, occurring on very sandy, dry hill slopes in the vicinity of Sarepta. Of value for sandy lands in the semiarid belt of the United States." (Meyer.)

32407. AGROPYRON sp.

From near Sarepta, Saratov Government, Russia.

"(No. 1709a, November 28, 1911.) A grass occurring here and there on very sandy soil. Grows in clumps. Of value as a forage grass on dry, sandy lands in the semiarid belt of the United States." (Meyer.)

32408. MEDICAGO SATIVA VARIA (Mart.) Urban.

Sand lucern.

From Krassny Koot, Samara Government, Russia.

"(No. 1710a, November 20, 1911.) A very strong-growing hybrid alfalfa having erect heavy stems which are well supplied with foliage. Obtained from Mr. W. S. Bogdan, at Krassny Koot, who is making extensive selection and hybridization experiments with *Medicago falcata* and has obtained a number of very promising types, some of which are suitable for raising exclusively for hay, while others are better for pasturing purposes.

"The climate around Krassny Koot is of a severely continental nature. The summers are hot and dry and the winters long and cold, with very little snow, as a rule. The medicagos selected there may prove especially suited to the drier portions of the western United States. The plant from which these seeds came bears Mr. Bogdan's No. 158, and is one of his best types." (Meyer.)

32409. MEDICAGO FALCATA L.

From near Sarepta, Saratov Government, Russia.

"(No. 1711a, November 28, 1911.) An alfalfa of moderate growth occurring on very sandy, dry hill slopes in a country where there is much limestone formation. Probably there are several types or, perhaps, even species in this lot of seed. To be tested in dry, sandy localities." (Meyer.)

32410. MEDICAGO sp.

From near Sarepta, Saratov Government, Russia.

"(No. 1712a, December 1, 1911.) An alfalfa occurring on dry, elevated lands along a ditch, of robust almost erect growth. Is either a form of *Medicago falcata* or *M. coerulea* which has been collected near Sarepta. Suitable for dry situations." (Meyer.)

32411. MEDICAGO FALCATA L.

From near Saratov, Russia.

"(No. 1713a, November 23, 1911.) An alfalfa of erect growth, found on dry, stony places on the hills near Saratov." (Meyer.)

32405 to 32424—Continued.**32412. MEDICAGO FALCATA L.**

From Krasny Koot, Samara Government, Russia.

"(No. 1714a, November 29, 1911.) This seed was presented by Mr. W. S. Bogdan. Among it there are all possible types, and it is recommended, therefore, for general naturalization purposes and should be sown in a dry northern locality for the selection of promising types." (*Meyer.*)

32413. ASTRAGALUS ALBICAULIS DC.

From near Sarepta, Saratov Government, Russia.

"(No. 1715a, November 28, 1911.) This plant occurs on dry, sandy hill slopes. Looks to be promising as a possible fodder plant for semiarid regions." (*Meyer.*)

Distribution.—The Caucasus region of southeastern Russia.

32414. CORONILLA VARIA L.

From near Saratov, Russia.

"(No. 1716a, November 23, 1911.) A perennial legume, found on dry hill slopes and in loess ravines. Roots sent under No. 993 (S. P. I. No. 32305): see this number for further remarks." (*Meyer.*)

32415. LATHYRUS SYLVESTRIS L.

From near Penza, Russia.

"(No. 1717a, November 17, 1911.) A very strong-growing perennial Lathyrus found between scrub. Of possible value for forage purposes on shady places in dry, cold regions." (*Meyer.*)

Distribution.—Western and southern Europe, extending from Scandinavia and the British Isles southward to Spain, and eastward through Italy, Servia, Bulgaria, Turkey, and central and southern Russia to the Caucasus region.

32416. BRASSICA JUNCEA (L.) Cass.

Mustard.

From Sarepta, Saratov Government, Russia.

"(No. 1718a, December 1, 1911.) Seed of the famous Sarepta mustard, which is extraordinarily strong and in great favor throughout Russia. To possess the right pungency this mustard requires a rich, blackish soil and a hot and dry summer, with nights not too warm. The region around Sarepta seems to supply such a climate, the summers being warm enough to ripen grapes in the open, although the vines are buried deeply in winter. It may be that this short, hot summer assists in making this mustard so strong, for the manager of a large mustard factory stated that seeds from Sarepta mustard grown in Tambov Government, a region also having black soil, but slightly cooler, do not possess the required strength. India-grown seed also was not as pungent as that cultivated near Sarepta. This may possibly be grown to advantage in certain sections of eastern Oregon.

"The seeds, besides being ground into powder, are often eaten sprinkled over fried meats or mixed in sauces and when used in this manner they give dishes an agreeable, spicy flavor. The oil expressed from them is not at all strong and is in very great demand for culinary purposes in the section around Sarepta, being much preferred to sunflower-seed oil, as the mustard is less adulterated.

"These seeds were obtained from the manager of the well-known mustard factory of J. C. Glitch, in Sarepta." (*Meyer.*)

32405 to 32424—Continued.

32417. *MALUS* sp.

Apple.

From near Sarepta, Saratov Government, Russia.

"(No. 1719a, November 28, 1911.) A genuine wild apple, occurring in the ravines in the vicinity of Sarepta. Sometimes seen as solitary shrubby specimens, sometimes as medium-sized trees in groves. The fruits are said to be very variable as regards size, flavor, and color. Of value possibly for breeding experiments in originating varieties of apples that are able to stand more drought than our present varieties." (*Meyer.*)

32418. *JUGLANS REGIA* L.

Walnut.

From Rostov, Russia.

"(No. 1720a, December 12, 1911.) A very large variety of walnut, being imported from Constantinople, but possibly grown somewhere in northern Persia or Asia Minor. Sells in Rostov at 30 kopecks (15 cents) a pound." (*Meyer.*)

32419. *CORYLUS AVELLANA* L.

Hazelnut.

From Rostov, Russia.

"(No. 1721a, December 12, 1911.) A very large variety of hazelnut, said to come from Persia, called *Persisky kurtshawi*. This name may be fictitious, as Armenian fruit dealers in Rostov are unreliable." (*Meyer.*)

32420. *CORYLUS AVELLANA* L.

Hazelnut.

From Rostov, Russia.

"(No. 1722a, December 12, 1911.) A very large variety of hazelnut, said to come from Constantinople, but cultivated probably somewhere in the south-western Caucasus or in Asia Minor." (*Meyer.*)

32421. *PHOENIX DACTYLIFERA* L.

Date.

From Rostov, Russia.

"(No. 1723a, December 12, 1911.) A very large variety of date of dark color and having little saccharine. Said to be grown in Persia and imported through Constantinople. New types may possibly be obtained from this lot." (*Meyer.*)

32422. *ACER TATARICUM* L.

Maple.

From near Sarepta, Saratov Government, Russia.

"(No. 1724a, November 28 and December 1, 1911.) A shrubby maple occurring on dry hill slopes and in gullies and ravines, effectually preventing the soil from being washed away, and of value for this reason in those semiarid sections of the United States where much land is being lost through erosion." (*Meyer.*)

Distribution.—Southeastern Europe, extending from Hungary and Bulgaria eastward to the Caucasus region, and in Asia Minor and Armenia.

32423. *EUONYMUS VERRUCOSUS* Scopoli.

From near Sarepta, Saratov Government, Russia.

"(No. 1725a, November 28, 1911.) A hardy shrub growing 3 to 5 feet in height, occurring in shady places. Of value as undergrowth beneath trees and tall shrubs in the parks and gardens of the semiarid sections of the United States." (*Meyer.*)

Distribution.—A shrub found in central and southern Europe and western Asia, extending from the eastern part of the German Empire eastward through Dalmatia, Bosnia, central and southern Russia to the Ural region of Siberia.

32405 to 32424—Continued.**32424. PRUNUS SPINOSA × DOMESTICA.****Plum.**

From Kozlov, Tambov Government, Russia.

"(No. 1726a, December 28, 1911.) This plum is a hybrid between *Prunus spinosa* and *P. domestica* var. *Green Reine Claude*; originated by Mr. I. V. Mijurin, Kozlov, Tambov Government, and temporarily named by him *Tjorn Sladky Chorny*, meaning 'sweet black sloe.' Scions sent under No. 1014 (S. P. I. No. 32671); see this number for further remarks." (*Meyer.*)

32425. ANNONA CHERIMOLA Miller.**Cherimoya.**

From San Jose, Costa Rica. Presented by Mr. Carlos Wercklé, Museo Nacional.

Received January 2, 1912.

Seeds.

32426. PERSEA AMERICANA Miller.**Avocado.**

From Musa Isle Grove, Miami, Fla. Presented by Mr. J. P. Roop, through Mr. H. F. Schultz. Bud wood sent to Mr. Edward Simmonds, gardener, in charge of Subtropical Plant Introduction Garden, Miami. Numbered January 15, 1912.

"*Roop.* A very good late variety which Mr. Roop states always produces generous crops of fruit which 'hang on' late in December and January. This season the *Trapp* and most other late avocados ripened and dropped their fruit earlier than usual, speaking well for the persistent properties of this variety. I consider the flavor superior to the *Trapp*; the seed always seems to be firm, but it is unfortunately rather large in proportion to the size of the fruit." (*Schultz.*)

32427. MEDICAGO SATIVA L.**Alfalfa.**

From India. Procured through Mr. F. Booth Tucker, Salvation Army, The Mall, Simla. Received January 15, 1912.

32428. PUERARIA THUNBERGIANA (S. and Z.) Benth.**Kudzu.**

From Sapporo, Japan. Presented by Prof. T. Minami, College of Agriculture, Tohoku Imperial University. Received January 2, 1912.

Root cuttings.

32429 to 32455.

From India. Collected by Mr. C. V. Piper, of the Bureau of Plant Industry. Received January 12, 1912.

Seeds of the following; quoted notes by Mr. Piper:

32429. BRACHIARIA ERUCIFORMIS (Smith) Griseb.

From Kirki.

"(No. 141, October 14, 1911.) One of the best pasture grasses in India, each plant producing a dense mass of fine stems a foot or more high. It produces seed in great abundance."

Distribution.—Southern Europe and Asia, extending from Italy eastward through Greece, Asia Minor, and northern Persia to India; also in Egypt, Abyssinia, and South Africa.

32429 to 32455—Continued.

32430. RYTILIX GRANULARIS (L.) Skeels.

(*Cenchrus granularis* L., 1771, *Mantissa Plantarum*, p. 575.)

The seeds of this grass were received under the name *Manisuris granularis* Swartz, 1778 (*Nova Genera et Species Plantarum*, p. 25), which is based on *Cenchrus granularis* L. However, Linnæus had published in 1771 (*Mantissa Plantarum*, pp. 164, 300) the generic name *Manisuris* with one species *M. myurus*, which is not now considered to be congeneric with *Cenchrus granularis* L., thus invalidating the use of the generic name *Manisuris* for the latter species. This fact was recognized by Kuntze, who proposed for *Cenchrus granularis* L. the name *Hackelochloa* (*Revisio Generum Plantarum*, 1891, pt. 2, p. 776). However, in 1830, Seringe (*Bulletin Botanique*, vol. 1, p. 219) had published the generic name *Ryttilix*, citing "*Manisuris granularis* et *myurus* Auct." and listing one species, *R. glandulosa*. While there is no description, the facts that *M. granularis* was cited first, that the name *R. glandulosa* is proposed and that "*glandulosa*" and "*granularis*" are considered to refer to the same plant characteristic, lead one to consider *Manisuris granularis* to be the type of the genus *Ryttilix*.

From Kirki.

"(No. 142, October 14, 1911.) An annual grass that may be valuable after the manner of crab-grass."

Distribution.—Found throughout the tropical region of India and is generally distributed in the Tropics of both hemispheres.

32431. INDIGOFERA LINIFOLIA (L. f.) Retzius.

From Kirki.

"(No. 143, October 14, 1911.) Said to be one of the best pasture legumes in India."

Distribution.—Throughout India from the Himalayas to Ceylon; also in Abyssinia, Afghanistan, the Malay Archipelago, and northern Australia.

32432. ALYSICARPUS LONGIFOLIUS (Rottl.) Wight and Arn.

From Kirki.

"(No. 144, October 14, 1911.) A tall, erect species being tested for hay at Kirki."

Distribution.—Throughout the plains of British India.

32433. SYNTERISMA SANGUINALIS (L.) Dulac.

From Kirki.

"(No. 145, October 14, 1911.) Similar to our common crab-grass."

32434. CROTALARIA ORIXENSIS Willd.

From Kirki.

"(No. 146, October 14, 1911.) A creeping species abundant in sorghum, etc., at Kirki. The green pods are eaten by boys."

Distribution.—Throughout the plains of India and in Abyssinia.

32435. MNESITHEA EXALTATA (L.) Skeels.

(*Aegilops exaltata* L., 1771, *Mantissa Plantarum*, p. 575.)

(*Ophiuros corymbosa* Gaertner f. 1805, *Fructibus et Seminibus Plantarum*, vol. 3, p. 3, pl. 181.)

The seeds of this grass were received under the name *Ophiuros corymbosa* (L. f.) Gaertn. f. In publishing the genus *Ophiuros*, Gaertner cited Rott-

32429 to 32455—Continued.

boellia Linn. and Juss., and described and figured two species. Under the first, *O. incurvata*, are cited the descriptions of *Aegilops incurvata* L. and *Rottboellia incurvata* L. f. Under the second, *O. corymbosa*, are cited the descriptions of *Aegilops exaltata* L. and *Rottboellia corymbosa* L. f., the latter of which is based on *Aegilops exaltata*, the specific name being changed because of *Rottboellia exaltata* L. f. appearing earlier on the same page of the Supplementum (1781, p. 114). The generic characterization covers both grasses; but the first species is more completely described, Gaertner not having any fertile flowers of the second, of which he remarks that it might prove to be very closely related to *Digitaria* if the flowers were better known. It would therefore seem necessary to consider the first species, *O. incurvata*, as the type of the genus *Ophiuros*. As *Aegilops exaltata* is not now considered to be congeneric with *O. incurvata* it must be referred to another genus. In 1829, Kunth (Revision des Graminées, vol. 1, p. 153) published the genus *Mnesithea* with one species, *M. laevis*, based on *Rottboellia laevis* Retzius. As this grass is considered to be congeneric with the species received as *Ophiuros corymbosa*, the latter is here placed in the genus *Mnesithea*, the earliest specific name, *exaltata*, being restored.

From Poona.

"(No. 147, October 13, 1911.) A rather coarse grass, but cut for fodder."

Distribution.—Found on dry hills at the base of the Himalayas, where it rises to an elevation of 3,500 feet, in the Khasi Hills and southward in the Dekkan Peninsula of India; also in the States of North Australia and Queensland in Australia.

32436. HEYLANDIA LATEBROSA (L.) DC.

From Kirki.

"(No. 148, October 14, 1911.) A prostrate legume abundant in the Dekkan. Said to be good fodder."

Distribution.—Throughout the tropical region of India from the valley of the Ganges to Ceylon.

32437. PANICUM TRYPPERON Schultes.

From Kirki.

"(No. 149, October 14, 1911.) A large annual *Panicum* producing enormous panicles 12 to 18 inches long and nearly as broad. These panicles break off and drift over the country after the manner of tumbleweeds. The grass is considered fair forage."

Distribution.—From India eastward to China and Borneo, and in tropical Africa.

32438. ISCHAEMUM PILOSUM (Klein) Hackel.

From Kirki.

"(No. 150, October 14, 1911.) A tall, rather coarse grass growing on comparatively low ground. It makes only fair forage."

Distribution.—In the Central Provinces and in the Dekkan Peninsula of India.

32439. ARTHRAXON LANCEOLATUS (Roxb.) Hochst.

From Kirki.

"(No. 151, October 14, 1911.) A grass growing about Poona in more or less shaded places, especially where somewhat moist."

32429 to 32455—Continued.

Distribution.—From the western Himalayas, where it rises to an elevation of 8,000 feet, southward to the Coromandel Coast of India, and eastward to the provinces of Chihli, Kiangsu, Hupeh, and Yunnan in China; also in Nubia and Abyssinia in northern Africa.

32440. *ANDROPOGON CARICOSUS* L.

From Kirki.

"(No. 152, October 14, 1911.) A grass abundant throughout northern and central India and considered excellent forage. Much of it is cut for hay."

32441. *ANDROPOGON ANNULATUS* Forsk.

From Kirki.

"(No. 153, October 14, 1911.) Very similar to the preceding, but with much more slender stems."

Distribution.—Throughout the plains and hills of India, and in tropical Africa, China, the Pacific islands, and in Australia.

32442. *PAROCHETUS COMMUNIS* Hamilton.

From Utakamand.

"(No. 154, October 24, 1911.) Collected on wet banks. The leaves are like white clover and the scapes bear one or two bright-blue flowers."

Distribution.—From the alpine slopes of the Himalayas southward and eastward to Ceylon and Burma in India, and in the Malay Archipelago to Java, also in tropical Africa.

32443 to 32448.

"A collection of grasses from Utakamand. All grow on the meadowy tops of the Nilgiri Hills. The climatic conditions in the Nilgiri Hills are very much like those of the coast region in California, the principal trees being Australian eucalypts and acacias and such California trees as the Monterey pine and *Cupressus macrocarpa*."

32443. *TRIPOGON FILIFORMIS* Nees.

"(No. 155, October 24, 1911.) A perennial grass forming a considerable element of the grassy meadows."

Distribution.—In India on the temperate slopes of the Himalayas at an elevation of 5,000 to 10,000 feet, between Dalhousie and Bhutan and on the Khasi Hills.

32444. *THEMEDA TRIANDRA* Forsk.

Probably variety *Themeda roylei* Hook. f.

"(No. 156, October 23, 1911.) An abundant element of the grassy meadows of the Nilgiri Hills and considered good forage."

Distribution.—In the drier parts of India from the lower Himalayas to Burma and Ceylon, and generally distributed in the Tropics of the Eastern Hemisphere.

32445. *ISCHAEMUM CILIARE VILLOSUM* (Nees) Hackel.

"(No. 157, October 25, 1911.) Locally abundant in the grassy meadows of the Nilgiri Hills."

Distribution.—From the eastern part of India southeastward through the Malay Archipelago to China and Australia.

32446. *BRACHYPODIUM SYLVATICUM* (Huds.) Beauv.

"(No. 158, October 23, 1911.) Common in shady places in the Nilgiri Hills at 6,000 feet altitude."

32429 to 32455—Continued.**32443 to 32448—Continued.**

Distribution.—In woods, hedges, and thickets throughout Europe and eastward through northern Asia to the provinces of Shingking and Hupeh, China.

32447. ANDROPOGON PERTUSUS INSCULPTUS (Hochst.) Hook.

"(No. 159, October 23, 1911.) This grass is abundant in the Nilgiri Hills near Utakamand, and is considered one of the most nutritious of the south India grasses for hay and pasturage."

Distribution.—Found with the species, which grows in southern Europe and Asia and northern Africa and Australia.

32448. ARUNDINELLA FUSCATA Nees.

"(No. 160, October 25, 1911.) Abundant on the Nilgiri Hills at 6,000 feet altitude and is considered to be an excellent pasture grass."

Distribution.—On the Nilgiri Hills at an elevation of 6,000 feet and at Rangoon, in India.

32449. CASSIA sp. (?)

From Utakamand.

"(No. 161, October 25, 1911.) Common throughout the Nilgiri Hills. Shrub, 3 to 6 feet high. Said to be American."

32450. RUBUS RUGOSUS Smith.

Raspberry.

From Utakamand.

"(No. 162, October 24, 1911.)"

"A tall climber, evergreen in mild climates, bearing comparatively large fruit. The fruit is dark red, turning black, makes delicious jam, and is borne the year around in the vicinity of Melbourne." (*Mueller, Select Plants.*)

Distribution.—In the upper part of the province of Nepal in northern India.

32451. RUBUS GOWREEPHUL Roxb.

From Utakamand.

"(No. 163, October 24, 1911.)"

Distribution.—On the slopes of the mountains in the northern part of India.

32452. PANICUM ANTIDOTALE Retz.

From Agra.

"(No. 164, October 7, 1911.) A species much like Guinea grass, but rather harsher. Of doubtful value."

Distribution.—Southern Asia, from Afghanistan southeastward through India to Ceylon, and in northern Africa and tropical Australia.

32453. RUBUS LASIOCARPUS Smith.

Raspberry.

From Bangalore.

"(No. 165, October, 1911.) A blackcap raspberry, native on the Nilgiris and cultivated about Bangalore. Larger than *Rubus occidentalis* and more juicy, but not so spicy in flavor. Will stand 20° F. Should be an excellent berry for the Southern States."

Distribution.—Temperate slopes of the Himalayas at an altitude of 5,000 to 10,000 feet, in northern India, and on the hills of southern India; also in Ceylon and Java.

32454. ANNONA CHERIMOLA Miller.

Cherimoya.

From Nilgiri Hills.

"(No. 166, October 25, 1911.) Grown at 5,000 feet elevation. An excellent fruit. This was introduced into India with the cinchona from Peru. (See note

32429 to 32455—Continued.

to this effect in Markham's Travels in India and Peru.) It is probable that all the cherimoyas in India are the progeny of this stock. Mr. George Oakes, who presented the seed, says that it comes absolutely true."

32455. TRICHOLAENA ROSEA Nees.

Natal grass.

From Poona.

"(No. 167.) Purchased from the Empress Botanic Gardens, Poona. In India this is cultivated only as an ornamental."

32457 and 32458. PRUNUS spp.

Seeds of the following, collected by Mr. W. F. Wight, of this Department, turned over to the Office of Foreign Seed and Plant Introduction January 9, 1912.

32457. PRUNUS sp.

Collected in Montmorency County, Mich. To be used for breeding purposes.

32458. PRUNUS MEXICANA S. Watson.

Plum.

Collected near Denison, Tex.

Distribution.—From western Tennessee southeastward to the vicinity of San Antonio, Tex.

32459. MACHILUS NANMU (Oliv.) Hemsl.

Nanmu.

From Tangho, Chiangchin, China. Presented by Mr. Albert W. Pontius, American consul, Chunking, China. Received January 19, 1912.

See Nos. 28128, 29485, and 30039 for previous introductions.

Seeds.

32460. CITRUS LIMETTA Risso.

Lime.

From Honolulu, Hawaii. Presented by Mr. J. E. Higgins, horticulturist, Hawaii Agricultural Experiment Station. Received January 19, 1912.

Cuttings.

Kusaie.

"This variety was introduced into Hawaii about 20 years ago from the island of the same name in the South Seas. It has proved to be a very good fruit-bearing tree, quite as healthy and vigorous as any of our limes, bearing fruit at almost all seasons of the year. The fruit is of medium to large size. The rind is rather thin and tender, which might bar this variety for commercial use. It is, however, an ideal lime for the family fruit garden." (*Higgins.*)

32461 and 32462. EUCALYPTUS spp.

From Sydney, New South Wales. Presented by Mr. R. T. Baker, curator, Technological Museum. Received January 20, 1912.

Seeds of the following; quoted notes taken from Baker and Smith, *Eucalypts and Their Essential Oils*, 1902. See this work for further description.

32461. EUCALYPTUS SMITHII R. T. Baker.

Gully-ash.

"A tall, quick-growing tree, sometimes attaining a height of 150 feet and a diameter of from 2 to 5 feet. Bark on old trees deeply furrowed, and in color dark gray to blackish up to the branches. It is famous for its eucalyptol oil."

Distribution.—A tree often 200 feet tall, found on steep mountain slopes in the southeastern part of New South Wales, Australia.

32461 to 32463—Continued.

32462. EUCALYPTUS UMBRA R. T. Baker. **Bastard white-mahogany.**

"A tall, foliaceous tree, attaining sometimes a height of 100 feet, with a dark-colored, stringy bark. Timber pale-colored, darker than 'White-mahogany,' *E. acmenoides* Schau. It is subject to the attacks of a borer, which, of course, deteriorates its quality as a marketable timber. It is hard, close-grained, but is rather an inferior timber to 'White-mahogany,' a fact well known to timber-getters."

Distribution.—A tree sometimes 100 feet tall, found in the northern part of New South Wales, Australia.

32463. ANNONA SQUAMOSA L.

Sweetsop.

From Papua. Presented by Mr. J. A. Hamilton, Port Moresby. Received January 20, 1912.

"The fruits of this variety are small, but flavor delicious; by cultivation it might be improved." (*Hamilton.*)

Seeds.

32464. DIOSPYROS SENEGALENSIS Perrott.

From Pretoria, Union of South Africa. Presented by Mr. C. L. Legat, Chief Conservator of Forests, Forest Department. Received January 22, 1912.

"A shrub or tree from 6 to 40 feet high or more. Wood much thought of by the natives, white, compact, or black in the center like ebony, and useful for many purposes. Fruit $\frac{3}{4}$ to 1 inch in diameter, edible. Range from Abyssinia and Mozambique on the east to Angola, the Kongo, and the Gold Coast on the west. Apparently very widely scattered, known as monkey guava in the west, and as aje in Abyssinia." (*Hiern, Ebenaceae, pp. 165-166.*)

32470 to 32477.

From Chios, Greece. Presented by Mr. N. J. Pantelides. Received January 26 and 27, 1912.

Cuttings of the following; quoted notes by Mr. Pantelides:

32470 to 32474. FICUS CARICA L.

Fig.

32470. "*Lombard.* Black with reddish interior."

32471. "*Vassilica* (Royal). Black."

32472. "*Ysterounlea.* This species bears fruit twice a year. They are very small but very sweet."

32473. "*Ambourcouna.* Black. Fruits twice a year."

32474. "*Metilinia.* White. These succeed also among oranges."

32475 to 32477. VITIS VINIFERA L.

Grape.

32475. "*Apatriana.* Black. Table variety."

32476. "*Crassera.* Black wine grapes noted for their great production."

32477. "*Arcoussia.* Rose-colored wine and table grapes. From these grapes was made the ancient wine of Chios. This vine is long lived, and succeeds as a climber; it may cover thus a pavilion of 100 square meters [120 square yards], and may yield up to a ton of fruits."

32478 and 32479. ANNONA CHERIMOLA Miller. Cherimoya.

From Costa Rica. Presented by Mr. Carlos Wercklé, San Jose. Received January 25, 1912.

"Seed from two anonas from Judge Castro Carillo. He says they are very good and of extraordinary size." (Wercklé.)

32480. AGAVE CANTALA (Haw.) Roxb. Manila maguey.

From Manila, Philippine Islands. Presented by Mr. O. W. Barrett, Chief, Division of Experiment Stations, Bureau of Agriculture, through Mr. Lyster H. Dewey, of the Bureau of Plant Industry. Received January 29, 1912.

"Manila maguey is cultivated in the Philippines and to a limited extent in India, where it produces the fiber known as Bombay aloe. It is cultivated on a large scale in Java, producing a very excellent quality of fiber which has heretofore been placed on the market under the misleading name "Java sisal." The Javanese growers now propose that this fiber shall be called "cantala." It grows well in Java on rich, loamy soils, where the heavy rainfall and lack of lime make it impossible to cultivate sisal or henequen to good advantage. This plant would probably grow well in the eastern part of Porto Rico." (Dewey.)

32481 and 32482.

From Honolulu, Hawaii. Presented by Mr. J. E. Higgins, horticulturist, Hawaii Agricultural Experiment Station. Received January 29, 1912.

Seeds of the following:

32481. CITRUS LIMETTA Risso. Lime.

Kusaie. Cuttings of this variety received under S. P. I. No. 32460.

32482. CARISSA GRANDIFLORA (E. Mey.) DC. Amatungulu.

32484 and 32485. HORDEUM spp. Barley.

From Hwaiyuan, Anhwei, China. Presented by Dr. Samuel Cochran, Hope Hospital. Received January 29, 1912.

Seeds of the following; quoted notes by Dr. Cochran:

32484. "This is called *Nu er ta meh*, which means 'daughter barley.'"

32485. "Barley with long awns called *Mi ta meh* or 'rice barley.'"

32486. RUBUS sp. Raspberry.

From Newara Eliya, Ceylon. Collected by Mr. C. V. Piper, of the Bureau of Plant Industry. Received January 29, 1912.

"(No. 85, August 27, 1911.) A spiny-stemmed red raspberry. Fruit small, smooth, in clusters. Flowers white. Stems ascending 4 to 10 feet." (Piper.)

32487. PHASEOLUS TRILOBATUS (L.) Schreber.

From Coimbatore, India. Collected by Mr. C. V. Piper, of the Bureau of Plant Industry. Received January 29, 1912.

"(October 26, 1911.) A trailing legume, abundant on low ground." (Piper.)

Distribution.—From the Himalayas, where it ascends to an elevation of 7,000 feet, to Ceylon and Burma; also in the Malay Archipelago and in Nubia and Abyssinia.

32488. STIZOLOBIUM sp.

From India. Presented by I. H. Burkhill, Office of the Reporter on Economic Products to the Government of India, Indian Museum, Calcutta, through Mr. C. V. Piper, of the Bureau of Plant Industry. Received January 29, 1912.

"Cultivated by the natives in the neighborhood of Darjiling, under the name *Kaoso Simbi*." (Piper.)

32489. STIZOLOBIUM sp.

From Bangalore, Mysore, India. Procured by Mr. C. V. Piper, of the Bureau of Plant Industry. Received January 29, 1912.

"Secured in the Agriculture Exhibit, October, 1911." (Piper.)

32490. ZEA MAYS L.**Corn.**

From Georgetown, Demerara, British Guiana. Presented by Mr. F. A. Stockdale, Assistant Director, Science and Agriculture and Government Botanic Gardens. Received February 1, 1912.

Creole.

32491 to 32655.

Seeds secured by Mr. C. V. Piper, of the Bureau of Plant Industry. Received November, 1911. Numbered February 1, 1912.

Quoted notes by Mr. W. J. Morse, of the Bureau of Plant Industry.

32491 to 32598. GLYCINE HISPIDA (Moench) Maxim. Soy bean.

From Calcutta, India. Received November 17, 1911, from the Economic Botanist.

32491 to 32533. "These are black with small seeds and appear identical as to seeds with S. P. I. Nos. 24678 to 24689 received from India in 1909.

32491. "Reg. No. 32045. From Purbaghur, United Provinces."

32492. "Reg. No. 32046. From Sultanpur, United Provinces."

32493. "Reg. No. 32047. From Lucknow, United Provinces."

32494. "Reg. No. 31577. From Patna Division."

32495. "Reg. No. 32175. From Nocha, Farukhabad, United Provinces."

32496. "Reg. No. 32176. From Bahadurpur, Farukhabad, United Provinces."

32497. "Reg. No. 32177. From Ismail Digon, Farukhabad, United Provinces."

32498. "Reg. No. 32178. From Pasgawn, Kheri, Oudh, United Provinces."

32499. "Reg. No. 32179. From Bijna, Kheri, United Provinces."

32500. "Reg. No. 32180. From Sansarpur, Kheri, United Provinces."

32501. "Reg. No. 32501. From Chandeswa, Sitapur, United Provinces."

32502. "Reg. No. 32182. From Bhagantipur, Sitapur, United Provinces."

32491 to 32655—Continued.**32491 to 32598—Continued.****32491 to 32533—Continued.**

- 32503.** "Reg. No. 32183. From Nimkhar, Sitapur, United Provinces."
- 32504.** "Reg. No. 32184. From Kauta, Unao, United Provinces."
- 32505.** "Reg. No. 32185. From Lalopur, Unao, United Provinces."
- 32506.** "Reg. No. 32186. From Mahanadpur, Unao, United Provinces."
- 32507.** "Reg. No. 32187. From Sanksoha, Basantpur, Futteghur, United Provinces."
- 32508.** "Reg. No. 32188. From Bahndolpur, Futteghur, United Provinces."
- 32509.** "Reg. No. 32189. From Khera Khurd, Mainpuri, United Provinces."
- 32510.** "Reg. No. 32190. From Lakhoura, Mainpuri, United Provinces."
- 32511.** "Reg. No. 32191. From Mainpuri, United Provinces."
- 32512.** "Reg. No. 32192. From Jaimoi, Mainpuri, United Provinces."
- 32513.** "Reg. No. 32193. From Nasipur, Mainpuri, United Provinces."
- 32514.** "Reg. No. 32194. From Tiswahisor, Hurdoi, United Provinces."
- 32515.** "Reg. No. 32195. From Atwa Karsot, Hurdoi, United Provinces."
- 32516.** "Reg. No. 32196. From Sanwaria, Hurdoi, United Provinces."
- 32517.** "Reg. No. 32197. From Aslapur, Hurdoi, United Provinces."
- 32518.** "Reg. No. 32198. From Jaipura, Hurdoi, United Provinces."
- 32519.** "Reg. No. 32199. From Naira, Hurdoi, United Provinces."
- 32520.** "Reg. No. 32200. From Barch, Etawah, United Provinces."
- 32521.** "Reg. No. 32201. From Bhoiya, Etawah, United Provinces."
- 32522.** "Reg. No. 32202. From Karayee, Etawah, United Provinces."
- 32523.** "Reg. No. 32203. From Nangawan, Etawah, United Provinces."
- 32524.** "Reg. No. 32204. From Etawah, United Provinces."
- 32525.** "Reg. No. 32205. From Etawah, United Provinces."
- 32526.** "Reg. No. 32209. From Shikohabad, United Provinces."

32491 to 32655—Continued.**32491 to 32598—Continued.****32491 to 32533—Continued.**

32527. "Reg. No. 32210. From Bewar, United Provinces."

32528. "Reg. No. 32211. From Lakhimpur, United Provinces."

32529. "Reg. No. 32212. From Langawar, United Provinces."

32530. "Reg. No. 32213. From Panhar, United Provinces."

32531. "Reg. No. 32399. From Jaunpur, United Provinces."

32532. "Reg. No. 32874. *Bhatmas*. From Darjiling."

32533. "Reg. No. 31565. From Kalimpong, Darjiling."

32534 to 32538. "Black, speckled with brown. In size and shape the seed is identical with S. P. I. Nos. 32491 to 32533."

32534. "Reg. No. 31785. From Poona, Bombay. Black, very similar to *Nuttall*, S. P. I. No. 17253."

32535. "Reg. No. 34013. From Gurhwal, United Provinces."

32536. "Reg. No. 32206. From Chakrata, Dehra Dun, United Provinces."

32537. "Reg. No. 32030. From Kashmir."

32538. "Reg. No. 31704. From Simla, Punjab."

32539 to 32541. "These are brown with medium-sized seed and very similar to S. P. I. No. 20011B."

32539. "Reg. No. 32208. From Chakrata, Tahsil, Dehra Dun, United Provinces."

32540. "Reg. No. 32372. From Kashmir."

32541. "Reg. No. 31702. From Simla, Punjab."

32542. "Reg. No. 31567. From Kalimpong, Darjiling. Brown, similar to S. P. I. No. 24673."

32543. "Reg. No. 32873. From Darjiling; very similar to S. P. I. No. 32542."

32544. "Reg. No. 32032. From Kalimpong, Darjiling. Brown, quite similar to S. P. I. No. 17258."

32545. "Reg. No. 31701. From Kangra, Punjab. Seed olive yellow, small, much flattened, with burnt-umber hilum."

32546. "Reg. No. 32870. *Bhatmas*. From Darjiling. Olive yellow, medium small with burnt-umber hilum."

32547. "Reg. No. 32872. *Bhatmas*. From Darjiling. Straw yellow, medium small, much flattened, hilum russet colored."

32548. "Reg. No. 32543. From Kilburn & Co., Calcutta. Olive yellow, identical with S. P. I. No. 26160."

32549. "Reg. No. 31787. From Poona, Bombay. This sample contains olive-yellow seed, similar to S. P. I. No. 19186, and straw-yellow seed, very similar to S. P. I. No. 17273."

32550. "Reg. No. 32265. From Kachin Hills, Burma. Straw colored with very small flattened seed, and hilum burnt umber."

32551. "Reg. No. 31568. From Kalimpong. Olive yellow with dark-brown hilum; similar to S. P. I. No. 24704 in size and shape."

32491 to 32655—Continued.**32491 to 32598—Continued.**

- 32552.** "Reg. No. 31781. From Poona, Bombay. Olive yellow, with slate-colored hilum; similar in size and shape to S. P. I. No. 24704."
- 32553.** "Reg. No. 31790. From Poona, Bombay. Very similar to S. P. I. No. 26160."
- 32554.** "Reg. No. 31782. From Poona, Bombay. Very similar to S. P. I. No. 32552."
- 32555.** "Reg. No. 32406. From a Chinese dealer of Tirectti Bazaar, Calcutta. Very similar to S. P. I. No. 26160."
- 32556.** "Reg. No. 31703. From Simla, Punjab. Quite similar to S. P. I. No. 22901."
- 32557.** "Reg. No. 31617. From Shillong. Straw yellow and brown seed. Identical with S. P. I. No. 24672."
- 32558.** "*Bhatmas*. Reg. No. 32871. From Darjiling. Straw yellow with very dark-brown hilum; similar to S. P. I. No. 24697 in size and shape."
- 32559.** "Reg. No. 31615. From Bhamo, Burma. Straw yellow, very similar to S. P. I. No. 17269."
- 32560.** "Reg. No. 31779. From Poona, Bombay. Straw yellow, very similar to S. P. I. No. 17269."
- 32561.** "Reg. No. 31778. From Poona, Bombay. Straw yellow, identical with S. P. I. No. 32560."
- 32562.** "Reg. No. 31786. From Poona, Bombay. Straw yellow, seed identical with S. P. I. No. 24702."
- 32563.** "Reg. No. 32405. From Chinese dealer of Tirectti Bazaar, Calcutta. Straw yellow, seed quite similar to S. P. I. No. 17278."
- 32564.** "Reg. No. 31776. From Poona, Bombay. Straw yellow, very similar to S. P. I. No. 24696."
- 32565.** "Reg. No. 31777. From Poona, Bombay. Straw yellow, identical with S. P. I. No. 32564."
- 32566.** "Reg. No. 32583. From Madras Museum, Government farm, Trivandrum. Straw yellow, very similar to S. P. I. No. 24699."
- 32567.** "Reg. No. 31789. From Poona, Bombay. Straw yellow, identical with S. P. I. No. 24699."
- 32568.** "Reg. No. 31780. From Poona, Bombay. Straw yellow, very similar to S. P. I. No. 24899."
- 32569.** "Reg. No. 31783. From Poona, Bombay. Straw yellow, identical with S. P. I. No. 24702."
- 32570.** "Reg. No. 31788. From Poona, Bombay. Straw yellow, identical with S. P. I. No. 24696."
- 32571.** "Reg. No. 31619. From Lashio, Hsenvi State, Northern Shan States, Burma. Straw yellow, very similar to S. P. I. No. 32559."
- 32572.** "*Sudawpa*. Reg. No. 31173. From Ruby Mines, Upper Burma. Straw yellow, nearly identical with S. P. I. No. 17269."

32491 to 32655—Continued.**32491 to 32598—Continued.**

- 32573.** "Reg. No. 31784. From Poona, Bombay. Straw yellow. Very similar to S. P. I. No. 14954."
- 32574.** "*Pe-nga-pi*. Reg. No. 32043. From Lashio, Northern Shan States, Burma. Straw yellow, with very small seed elliptical in shape and hilum russet colored."
- 32575.** "Reg. No. 32214. From Myitkyina, Burma. Straw yellow, identical with S. P. I. No. 30574."
- 32576.** "Reg. No. 31803. From Naga Hills, Assam. Straw yellow, very similar to S. P. I. No. 14954."
- 32577.** "Reg. No. 31803. From Naga Hills, Assam. Straw yellow, identical with S. P. I. No. 30576."
- 32578.** "Reg. No. 31626. From Tiddim, Chin Hills, Burma. Straw yellow, very similar to S. P. I. No. 24674."
- 32579.** "Reg. No. 31566. From Kalimpong. Straw yellow, identical with S. P. I. No. 24674."
- 32580.** "Reg. No. 31569. From Kalimpong. Straw yellow, very similar to S. P. I. No. 24674."
- 32581.** "Reg. No. 32216. From Myitkyina, Burma. Straw yellow, very similar to S. P. I. No. 32580."
- 32582.** "Reg. No. 31252. *Pyin*. From Maubin, Lower Burma. Straw yellow, with small seeds much flattened and brown hilum."
- 32583.** "Reg. No. 31251. From Katha, Burma. Straw yellow, identical with S. P. I. No. 32582."
- 32584.** "Reg. No. 32075. From Myitkyina, Burma. Straw yellow, with brown hilum, similar to S. P. I. No. 32574, in size and shape."
- 32585.** "Reg. No. 31426. From Nagpur, Central Provinces. Straw yellow, very similar to S. P. I. No. 32582."
- 32586.** "Reg. No. 32217. From Myitkyina, Burma. Straw yellow, very similar to S. P. I. No. 32584."
- 32587.** "Reg. No. 31249. From Thaton, Upper Burma. Straw yellow, very similar to S. P. I. No. 32584."
- 32588.** "Reg. No. 32215. From Myitkyina, Burma. Straw yellow, very similar to S. P. I. No. 32584."
- 32589.** "Reg. No. 31616. From Lower Chindwin, Burma. Straw yellow, similar to S. P. I. No. 32584."
- 32590.** "Reg. No. 32074. From Katha, Burma. Straw yellow, similar to S. P. I. No. 32580."
- 32591.** "Reg. No. 31614. From Mandalay, Burma. Straw yellow, similar to S. P. I. No. 32580."
- 32592.** "Reg. No. 32592. From Gurhwal, United Provinces. Straw yellow, similar to S. P. I. No. 32580."
- 32593.** "Reg. No. 31574. From Haka, Chin Hills, Burma. Straw yellow, identical with S. P. I. No. 24672."
- 32594.** "Reg. No. 32029. From Kashmir. Straw yellow, identical with S. P. I. No. 22901."

32491 to 32655—Continued.**32491 to 32598—Continued.**

32595. "Reg. No. 32373. From Kashmir. Straw yellow, identical with S. P. I. No. 32594."

32596. "Reg. No. 32012. Yields 12.55 per cent of oil. From Gurhwal, United Provinces. Straw yellow (cloudy), in size and shape similar to S. P. I. No. 32594."

32597. "Reg. No. 31250. *Pe-kyat* or *Pe-bok*. From Mandalay. Straw yellow, very similar to S. P. I. No. 32580."

32598. "Reg. No. 32207. From Chakrata, Tahsib, Dehra Dun, United Provinces. Straw yellow, very similar to S. P. I. No. 32596."

32599 to 32605. PHASEOLUS CALCARATUS Roxb.

32599. "Reg. No. 31806. From Naga Hills, Burma. Mottled."

32600. "Reg. No. 31808. From Kerhn, Naga Hills, Burma. Brown."

32601. "Reg. No. 31708. From Myitkyina, Burma. Brown."

32602. "Reg. No. 32396. From Kerhn, Naga Hills, Burma. Mottled."

32603. "Reg. No. 31709. From Myitkyina, Burma. Black."

32604. "Reg. No. 32031. From Kashmir, India. Black."

32605. "Mashyan. Reg. No. 32878. From Darjiling. Brown."

32606. PHASEOLUS RADIATUS L.

"Mashyan. Reg. No. 32880. From Darjiling. Maroon."

32607. PHASEOLUS RADIATUS L.

"Reg. No. 32877. From Darjiling. Mottled."

32608. PHASEOLUS MAX L.

"Bought on the market at Trichinopoly, August 31, 1911. (No. 68.)"

32609. VIGNA CYLINDRICA (Stickman) Skeels. Catjang.

(*Phaseolus cylindricus* Stickman, 1759, Herbarium Amboinense, in Linnæus's *Amœnitates Academicæ*, vol. 4, p. 132.)

The catjang bean has heretofore been listed in the inventories as *Vigna catjang* (Burm.) Walpers, 1839 (Linnæa, vol. 13, p. 533), which was based on *Dolichos catjang* published in 1768 by N. L. Burmann (*Flora Indica*, p. 161.) However, Stickman in 1759 had published the name *Phaseolus cylindricus* for the plant described and figured by Johannes Burmann (Rumph's *Herbarium Amboinense*, vol. 5, 1747, p. 383, pl. 139, fig. 1), which is cited under *Dolichos catjang* by N. L. Burmann. It is therefore necessary to use the specific name *cylindricus* for the catjang bean.

"Bought on the market at Trichinopoly, August 31, 1911. (No. 65.) Clay."

32610. DOLICHOS LABLAB L. Bonavist bean.

"Bought on the market at Trichinopoly, August 31, 1911. (No. 67.) White."

32611. DOLICHOS LABLAB L. Bonavist bean.

"Bought on the market at Trichinopoly, August 31, 1911. (No. 66.) Buff."

32612. DOLICHOS BIFLORUS L.

"From the market at Trichinopoly, August 11, 1911. (No. 70.)"

32491 to 32655—Continued.

32613. *SYNTHESISMA CONSANGUINEA* (Gaud.) Skeels.

(*Digitaria consanguinea* Gaudichaud, 1826, in Freycinet, Voyage Autour du Monde, Botanique, p. 410.)

The seeds of this grass, received as an unidentified *Syntherisma*, prove to be those of the species *consanguinea*. This species seems not to have been given a binomial name under the genus *Syntherisma*, the proper designation for the grasses sometimes known as *Digitaria*.

"A slender species growing in the Calcutta Botanical Gardens in great abundance. (No. 103, September 8, 1911.)"

Distribution.—This was first found in the Hawaiian Islands, and is now known to grow in the Malay Archipelago and in Polynesia.

32614. *MNESITHEA LAEVIS* (Retz.) Kunth.

"A slender, erect species, abundant in the Calcutta Botanical Gardens. (No. 102, September 8, 1911.)"

Distribution.—Southern Asia, extending from Afghanistan eastward to Ceylon and Burma, and through the Malay Archipelago to Java.

32615 to 32621. *STIZOLOBRUM* spp.

"Most of these forms were included by Hasskarl under the name *Mucuna velutina*, but their exact botanical relations remain to be established. Secured from the agricultural experiment station, Buitenzorg, Java."

32615. "Seeds ashy with indefinite smoky spots."

32616. "Seeds pale greenish."

32617. "Seeds greenish buff."

32618. "Seeds liver colored."

32619. "Seeds black."

32620. "Seeds brownish marbled and speckled with brown and black."

32621. "Seeds ash gray, marbled and speckled with brown and black."

32622 to 32631. *VIGNA SESQUIPEDALIS* (L.) W. F. Wight.

"Seeds received from Java, November, 1911."

32622. "*Glejor*. Brown, very similar to S. P. I. No. 21561."

32623. "*Tyinde*. Brown, identical with S. P. I. No. 32622."

32624. "*Pandjang*. Brown, very similar to S. P. I. No. 32623."

32625. "*Agel*. Brown, identical with S. P. I. No. 32624."

32626. "*Kroepoek*. Brown, lighter than S. P. I. No. 32625."

32627. "*Poejoek*. Brown, identical with S. P. I. No. 32626."

32628. "*Oesves*. Brown, identical with S. P. I. No. 32626."

32629. "*Dadap*. Black."

32630. "*Palembang*. Black."

32631. "*Roedjii*. Black."

32632 to 32638. *VIGNA SINENSIS* (Torner) Savi.

Cowpea.

"From Java. Received November, 1911."

32632. "*Roedjii*. Reddish brown, quite similar to S. P. I. No. 17369, but seeds smaller."

32491 to 32655—Continued.

32632 to 32638—Continued.

32633. "*Dadap*. Reddish brown, identical with S. P. I. No. 32632."

32634. "*Dadap*. Yellowish, quite similar to S. P. I. No. 29232."

32635. "*Roedjii*. Yellowish, very similar to S. P. I. No. 21509A."

32636. "Originally from Marseille. Very similar to S. P. I. No. 17425."

32637. "*Blackeye*, identical with S. P. I. No. 21297."

32638. "*No. 5 Groeboeg*. Speckled reddish brown."

32639 to 32655. "Seed received from Java, November, 1911."

32639. *VIGNA CYLINDERICA* (Stäckman) Skeels.

Oatjang.

"*Mantri*. Browneye."

32640 to 32644. *PHASEOLUS CALCARATUS* Roxb.

32640. "*Katjang Kajoe Aro*. Black."

32641. "*Katjang Kajoe Aro*. Brown."

32642. "*Katjang Kajoe Aro*. Mottled."

32643. "*Katjang Kajoe Aro*. Mottled, but more of a reddish brown color."

32644. "*Katjang Kajoe Aro*. Light brown."

32645. *CANAVALI GLADIATUM* (Jacq.) DC.

Sword bean.

"*Reuzen Canavallia*. Red."

32646. *CANAVALI GLADIATUM* (Jacq.) DC.

Sword bean.

"*Reuzen Canavallia*. Yellow."

32647. *CANAVALI ENSIFORME* (L.) DC.

Jack bean.

32648. *GLYCINE HISPIDA* (Moench) Maxim.

Soy bean.

"Dull black, identical with S. P. I. No. 16790B, a selection from *Cloud*, S. P. I. No. 16790."

32649. *GLYCINE HISPIDA* (Moench) Maxim.

Soy bean.

"Straw yellow, very similar to S. P. I. No. 24695."

32650. *CRACCA VILLOSA HIRTA* (Hamil.) Kuntze.

Distribution.—Throughout the plains of India from the base of the Himalayas to Ceylon and Malakka and eastward through the Malay Archipelago to Java.

32651. *CLITORIA LAURIFOLIA* Poir.

Distribution.—A suberect undershrub found in Brazil and northward to Colombia, and in the West Indies; also in Malakka and Java.

32652. *CASSIA PATELLARIA* DC.

Distribution.—A herbaceous perennial found in the vicinity of Orizaba in southern Mexico and southeastward through Central America to the northern part of South America; also in the West Indies.

32653 to 32655. *ANDROPOGON BORGHUM* (L.) Brot.

32653. "Black."

32654. "Red."

32655. "Dark red."

32656. DIOSPYROS KAKI L. f.**Persimmon.**

From Ormond, Fla. Presented by Mr. James P. Vining, Bretton Inn. Received February 2, 1912.

Ormond Winter. Fruits of this variety were received in the middle of January. They were of excellent flavor and one among the lot was found to be seedless.

Cuttings.

32657 to 32659.

From Bombay, India. Purchased from Ralli Bros. Received January 30, 1912.

Seeds of the following:

32657. DOLICHOS BIFLORUS L.

"*Kulthi.*"

32658. PHASEOLUS ACONITIFOLIUS Jacq.

"*Muth.*"

32659. VIGNA CYLINDRICA (Stickman) Skeels.

Catjang.

"*Chowli.*"

32660. RADICULA ARMORACIA (L.) Robinson.**Horse-radish.**

From Moscow, Russia. Received through Mr. Frank N. Meyer, agricultural explorer, February 2, 1912.

"(No. 1020, January 8, 1912.) A variety of horse-radish, coming from Soosdal, Vladimir Government, Russia, famous throughout the country for its fine qualities and said to be the best horse-radish in Europe. Is in special demand in Russia during the winter holidays. To be tested in the northern United States in deep, rich soil." (*Meyer.*)

32661. TRITICUM AESTIVUM L.**Wheat.**

From Njoro, British East Africa. Presented by Mr. W. G. Sewall. Received January 23, 1912.

Rieti.

32662 to 32676.

From Kozlov, Tambov Government, Russia. Received through Mr. Frank N. Meyer, agricultural explorer, January 29, 1912.

Cuttings of the following:

32662. AMYGDALUS NANA × DAVIDIANA.

From Kozlov, Tambov Government, Russia.

"(No. 1005, December 27, 1911.) This species was originated by Mr. I. V. Mijurin at Kozlov, with the idea of creating a perfectly hardy peach, able to withstand the severe climate of central Russia. This hybrid produces non-edible fruits and has the characteristic growth of *Amygdalus davidiana*, while the form and appearance of the fruit is more or less that of *A. nana*. Said to be very floriferous and extremely showy in springtime. Possesses value as an ornamental tall shrub for the northern United States and may serve as a hybridization factor in creating races of perfectly hardy peaches, as Mr. Mijurin's experiences were that while *A. davidiana* and *A. nana* do not hybridize with *A. persica*, this hybrid does." (*Meyer.*)

32662 to 32676—Continued.**32663. PRUNUS ARMENIACA L.****Apricot.**

From Kozlov, Tambov Government, Russia.

"(No. 1006, December 27, 1911.) An apricot originated by Mr. I. V. Mijurin in Kozlov, said to bear large, yellowish fruits of good flavor. Withstands unprotected the severe climate of central Russia and is probably the hardiest variety of apricot known. Of unusual value as a novel hardy fruit for the northern United States." (Meyer.)

32664. PRUNUS FRUTICOSA Pallas.

From Kozlov, Tambov Government, Russia.

"(No. 1007, December 27, 1911.) A variety of Siberian cherry, said to bear very abundantly, fruits of large size. Originated by Mr. I. V. Mijurin in Kozlov. Of high value like preceding number." (Meyer.)

32665. PRUNUS FRUTICOSA Pallas.

From Kozlov, Tambov Government, Russia.

"(No. 1008, December 27, 1911.) A variety of Siberian cherry, of very dwarf growth, and bears sweet fruits, which is a great rarity among this species. Originated by Mr. I. V. Mijurin in Kozlov. Of high value like the preceding numbers." (Meyer.)

32666. SORBUS AUCUPARIA × AMERICANA.**Rowan.**

From Kozlov, Tambov Government, Russia.

"(No. 1009, December 27, 1911.) A rowan bearing large, sweet-flavored fruits of dark-red color, which are said to be pleasant eating. Originated by Mr. I. V. Mijurin at Kozlov. Of special value like No. 1006 (S. P. I. No. 32663)." (Meyer.)

32667. RIBES AUREUM Pursh.**Golden currant.**

From Kozlov, Tambov Government, Russia.

"(No. 1010, December 27, 1911.) A variety of currant said to bear large fruits of good, sweet flavor, ranging in colors from dark purple to pale yellow. Extremely hardy, thriving on even the poorest soils. Originated by Mr. I. V. Mijurin at Kozlov. Of particular value for the northern sections of the United States." (Meyer.)

32668. ROSA SPINOSISSIMA × RUGOSA.**Rose.**

From Kozlov, Tambov Government, Russia.

"(No. 1011, December 27, 1911.) A rose of low, dense growth and exceptionally hardy. Flowers said to be large and of a pale-rose color. Originated by Mr. I. V. Mijurin at Kozlov. Of special value for the northern United States." (Meyer.)

32669. PRUNUS SPINOSA × DOMESTICA.**Plum.**

From Kozlov, Tambov Government, Russia.

"(No. 1012, December 28, 1911.) A plum, being a hybrid between *Prunus spinosa* and *P. domestica*, Green Reine Claude variety. Originated by Mr. I. V. Mijurin at Kozlov and temporarily named by him *Bjeli Tjorn*, meaning white sloe. Fruits almost round, medium size, of yellowish white color, and good keeping qualities. Trees of medium size, rather slow in growth, but are heavy bearers and exceptionally hardy. Of high value for the colder sections of the United States." (Meyer.)

32663 to 32676—Continued.

32670. *PRUNUS SPINOSA* × *DOMESTICA*.

Plum.

From Kozlov, Tambov Government, Russia.

"(No. 1013, December 28, 1911.) A plum of the same parentage as the preceding numbers. Originated by Mr. I. V. Mijurin at Kozlov, and temporarily named by him *Dessertnaia Tjorn Chorny*, meaning black dessert sloe. Fruits dark purple, not very large, of sweet, characteristic spicy flavor, and possessing good keeping and shipping qualities. Trees of vigorous growth. Of high value like the preceding number." (Meyer.)

32671. *PRUNUS SPINOSA* × *DOMESTICA*.

Plum.

From Kozlov, Tambov Government, Russia.

"(No. 1014, December 28, 1911.) A plum of the same parentage as the preceding numbers. Originated by Mr. I. V. Mijurin at Kozlov and temporarily named by him *Tjorn Sladky Chorny*, meaning sweet black sloe. Fruits of a dark-purplish color, medium size, and having a very sweet flavor, with an after-taste all their own. The trees are very productive and of vigorous growth. Of high value like the preceding numbers." (Meyer.)

Seed received under S. P. I. No. 32424.

32672. *PRUNUS SPINOSA* × *DOMESTICA*.

Plum.

From Kozlov, Tambov Government, Russia.

"(No. 1015, December 28, 1911.) A plum of the same parentage as the preceding numbers. Originated by Mr. I. V. Mijurin at Kozlov, and temporarily named by him *Zimni Tjorn Chorny*, meaning black winter sloe. Fruits of dark-purple color, medium size, of sweet, spicy flavor, and possessing admirable keeping and shipping qualities, lasting as long as three months. They do not drop easily from the trees even when fully ripe. Trees of vigorous, rather tall growth, and very hardy. Of high value like the preceding numbers." (Meyer.)

32673. *PRUNUS SPINOSA* × *DOMESTICA*.

Plum.

From Kozlov, Tambov Government, Russia.

"(No. 1016, December 28, 1911.) A plum of the same parentage as the preceding numbers. Originated by Mr. I. V. Mijurin at Kozlov and temporarily named by him *Reine Claude Zolotisti*, meaning Golden Reine Claude. Fruits of medium size and a beautiful yellow color; shape spherical, slightly flattened; juicy; taste sweet and spicy. Of good keeping and shipping qualities and considered an excellent market variety. Trees of medium growth, very healthy and cold resistant. Of high value like the preceding numbers." (Meyer.)

32674. *PRUNUS AVIUM* L.

Cherry.

From Kozlov, Tambov Government, Russia.

"(No. 1017, December 28, 1911.) A variety of cherry originated by Mr. I. V. Mijurin at Kozlov, and named by him *Knyashnaia Severa*, meaning Queen of the North. Fruits large, of pale-red color, and fresh sour-sweet flavor, ripening toward the end of June; possesses excellent shipping and keeping qualities and persists on the trees even when over ripe. Trees of vigorous, straight growth, making but few side branches; trunks smooth and clean. This variety seems to give special satisfaction in dry, cold climates like, for instance, that of Samara Government, Russia, where cherries as a rule grow very poorly. It is considered in Russia to be a decided acquisition to their hardy fruit trees and will no doubt be found of special value in the northern sections of the United States." (Meyer.)

32662 to 32676—Continued.**32675. CYDONIA OBLONGA** Miller.**Quince.**

From Kozlov, Tambov Government, Russia.

"(No. 1018, December 28, 1911.) A quince selected by Mr. I. V. Mijurin at Kozlov; is able to withstand successfully the severe climate of central Russia, where quinces ordinarily perish when the thermometer drops to -20° C. (-4° F.) This variety has stood -35° C. (-31° F.) and remained unhurt. Fruits medium size, of oblong shape. Valuable as a home fruit for the northern United States." (Meyer.)

32676. CYDONIA OBLONGA Miller.**Quince.**

From Kozlov, Tambov Government, Russia.

"(No. 1019, December 28, 1911.) A variety of quince selected by Mr. I. V. Mijurin at Kozlov, bearing medium-sized, round fruits. For further remarks see the preceding number." (Meyer.)

32678. AMYGDALUS PERSICA NECTARINA Ait.**Nectarine.**

Grown at the Plant Introduction Field Station, Chico, Cal. Numbered February, 1912.

Crosby. Same as S. P. I. No. 11777, budded on *Amygdalus davidiana*, S. P. I. No. 26604.

32679. MYRCIARIA EDULIS (Vell.) Skeels.

From Paraguay. Presented by Dr. Moisés S. Bertoni, Estacion Agronomica, Puerto Bertoni. Received February 3, 1912.

"*Ih va hai.*"

32680 to 32689. TRITICUM spp.**Wheat.**

From Argentina. Presented by Dr. Carlos Thays, Director, Botanic Garden, Buenos Aires. Received January 30, 1912.

Seeds of the following; quoted notes by Dr. Thays:

32680. TRITICUM DURUM Desf.

"*Tangaro.* Cultivated in the central pampas. Production 1,900 kilos [about 2 tons] per hectare [2.47 acres]."

32681 to 32689. TRITICUM AESTIVUM L.

32681. "*Barleta.* Cultivated in the southern part of the province of Buenos Aires. Production 1,440 kilos per hectare."

32682. "*French Red.* From the western part of the province of Buenos Aires. Yield 1,550 kilos per hectare."

32683. "*Tusella.* From central pampas. Yield 1,480 kilos per hectare."

32684. "*Barleta.* From Chubut. Yield 1,900 kilos per hectare."

32685. "*Barleta.* From the south of Cordoba. Yield 1,690 kilos per hectare."

32686. "*Australian.* From southern Santa Fe. Yield 1,380 kilos per hectare."

32687. "*Hungarian.* From central pampas. Yield 1,290 kilos per hectare."

32688. "*Barleta.* From Rio Negro. Yield 1,320 kilos per hectare."

32689. "*French.* From southern San Luis. Yield 1,550 kilos per hectare."

32691 to 32694. PERSEA spp.

From the State of Puebla, Mexico. Presented by Mr. William W. Canada, American consul, Vera Cruz. Received February 3, 1912.

Seeds of the following:

32691. PERSEA AMERICANA Miller.

Avocado.

32692. PERSEA MEXICANA (Meisn.) Hemsl.

Distribution.—The province of Vera Cruz in southern Mexico.

32693. PERSEA sp.

32694. PERSEA LINGUE (Ruiz and Pav.) Nees.

See No. 24208 for description.

32695. PHASEOLUS VULGARIS L.

Bean.

From Paraguay. Presented by Dr. Moisés S. Bertoni, Estacion Agronomica, Puerto Bertoni. Received February 3, 1912.

32696. ANACARDIUM OCCIDENTALE L.

Cashew.

From State of Rio de Janeiro, Brazil. Presented by Mr. R. E. Demaret, Sao Paulo. Forwarded by Mr. C. A. Lull, Tiffin, Ohio. Received February 1, 1912.

See No. 5202 for description.

Seeds.

32697 to 32702.

From Chelsea, London, England. Purchased from James Veitch & Sons (Ltd.). Received February 5, 1912.

Plants of the following; quoted notes by James Veitch & Sons:

32697. ROSA WILLMOTTIAE Hemsl.

Rose.

"A very pretty species with single, rosy carmine flowers, 1 inch to 1½ inches in diameter, which are freely produced during June. Very distinct from any other rose in cultivation."

Distribution.—On the slopes of the Sangpan Mountains near the Tibetan frontier of western China, at an elevation of 9,500 to 11,000 feet.

32698. BERBERIS POLYANTHA Hemsl.

Barberry.

"A deciduous shrub, 5 to 6 feet high, with yellow flowers, followed by coral-red fruits. Bright-green obovate leaves borne in clusters of about eight each."

Distribution.—Collected in western China.

32699. BERBERIS VERRUCULOSA Hemsl. and Wilson.

Barberry.

"A dense-growing evergreen shrub about 2 feet high. Leaves leathery, ovate, spiny, shining above, glaucous beneath. Flowers yellow, borne in pairs, succeeded by violet-purple fruits."

Distribution.—An evergreen shrub found on the mountains in the vicinity of Tatienlu, in the Province of Szechwan, in China.

32700. BERBERIS JAPONICA BEALEI (Fortune) Skeels.

Barberry.

"Not far from the town of Tun Chee in the green-tea country of Hankow, China. A handsome evergreen species somewhat resembling *Berberis fremontii* of northern Texas." (Dr. W. Van Fleet.)

See No. 31244 for previous introduction.

32697 to 32702—Continued.**32701. BERBERIS GAGNEPAINI** C. K. Schneider.**Barberry.**

"An elegant evergreen barberry of compact growth, flowering freely during June in this country. The pale-yellow flowers are succeeded by glaucous purple berries."

Distribution.—Slopes of the mountains at an elevation of 10,000 feet in north-eastern India and western China.

32702. IRIS WILSONI C. H. Wright.**Iris.**

"A new species, resembling *Iris sibirica* in habit. Flowers pale yellow, outer segments veined red brown, borne on stems 8 to 12 inches high. First flowered in July, 1909, at Coombe Wood."

Distribution.—Known only from western China.

32703. CAMPOMANESIA sp.

From Puerto Bertoni, Paraguay. Presented by Dr. Moisés S. Bertoni, Estacion Agronomica. Received February 6, 1912.

"*Inavira*."

32704 and 32705.

From Inhamban, Portuguese East Africa. Presented by Mr. Pliny W. Keys, Methodist Episcopal Mission. Received February 6, 1912.

Seeds of the following; quoted notes extracted from Sims's Forest Flora of Portuguese East Africa:

32704. GARCINIA sp.

"*Pembe*. Either a branched bush, an erect tree, or a bushy tree; in each case the stems set with numerous firm, little, more or less evergreen branches, which give the tree a pyramidal shape. Leaves usually in threes or opposite. Fruit 1 to 2 inches long, oblong, edible, yellow at first or when ripe, two seeded, and used by the natives to make a fermented liquor. Abundant in sandy soil through the M'Chopes country to Inhamban."

32705. STRYCHNOS GERRARDI N. E. Brown.

"*Quaqua*. A small tree, 3 to 10 meters high, without thorns, and with exceedingly variable leaves. Fruit one celled, globose, 5 to 7 centimeters in diameter, small, thin, spotted, with a hard shell, and numerous flat seeds lying in an acidulous edible pulp. Abundant from Natal to Inhamban, and especially on the sandy soils."

32706. ABIES NUMIDICA De Lannoy.

From Babois, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received February 6, 1912.

"This tree grows with the cedar. It is a very splendid tree, flourishing here at 1,800 meters." (*Trabut*.)

Distribution.—A tree, sometimes 75 feet high, found on the slopes of mountains at an elevation of 5,000 to 7,000 feet, in the Province of Constantine, in the northern part of Algeria.

32708 to 32712. ARALIA CORDATA Thunb.**Udo.**

From Yokohama, Japan. Purchased from L. Boehmer & Co. Received February 7, 1912.

Roots of the following:

32708. "*Shiro oku*."

32711. "*Oku aka*."

32709. "*Kan udo*."

32712. "*Shiro wase*."

32710. "*Wase aka*."

32713 to 32725. PHOENIX DACTYLIFERA L.**Date.**

From Egypt. Procured through Mr. A. Aaronsohn, Managing Director, Jewish Agricultural Experiment Station, Haifa, Palestine. Received February 2, 1912.

"A collection of date palms secured from Upper Egypt by Mr. Aaronsohn under my direction. The object of the expedition was primarily to secure the *Wahi* date, of which specimens were secured by Mr. David Fairchild in 1900-1901. This name, as was pointed out by Mr. H. A. Rankin in 1904, is merely an English translation of the Arabic word meaning 'oasis date.' Mr. Rankin further suggests that the dates at Fayum, such as Mr. Fairchild secured, are probably from the oasis of Bahriyeh. Prof. G. Schweinfurth, of Berlin, informed me in July, 1911, that a large date by this name is imported into Egypt from the oasis of El Khargeh.

"Besides this variety, Mr. Aaronsohn hoped to get some of the fine Nubian varieties that have been reported by various travelers. In October, 1911, Mr. Aaronsohn found at Aswan trees of the *Wahi* variety which originally came from the oasis of Khargeh. He was unable to secure offshoots from these particular trees. Mr. Aaronsohn did, however, secure a number of offshoots of other varieties of considerable importance, as shown in the following list. The most important of these is probably the *Sultany*. If these offshoots prove true to name this one variety would undoubtedly repay the expense of the whole trip." (*Walter T. Swingle*.)

32713. "*Sukkoti*."¹ This variety comes from the village of Sukka, in Nubia, and along with those of Say is said to be one of the best that grows on the banks of the Nile. Burckhardt (Nubia, ed. 2, p. 752) says: 'They are of the largest kind, generally 3 inches long. As there is no navigation northward through the Batn el Hadjar, these dates reach northern parts of Nubia only in small quantities at present.' The date is listed by Delchevalerie as a Nubian variety." (*Walter T. Swingle*.)

32714. "*Gundela*."¹ This is probably the Gondaila of Fletcher's report in Bulletin No. 28 of the Department of Lands and Agriculture at Bombay, page 17. He states that it ripens in September, grows in sandy soil, and is a large, yellowish brown variety." (*Walter T. Swingle*.)

32715. "*Kilma*, or *Sultany*."¹ According to Lipsius this is considered the best date in Nubia and is believed to keep for two years. This date, perhaps the most celebrated of the Nubian country, was formerly exported in some quantities through Egypt to Constantinople, where it is said to have gone to the Sultan's palace. It is perhaps the most famous of the Upper Egyptian varieties." (*Walter T. Swingle*.)

32716. "*Ibrimy*." A famous variety common in the district of Babir, and in Lower Nubia. It ripens in September and is a brown color. The fruit is said to resemble somewhat the carob in flavor." (*Walter T. Swingle*.)

¹ "Drying dates from Upper Egypt." (Aaronsohn.)

32718 to 32725—Continued.

32717. "*Hayany*. A variety from the town of Hayany in Upper Egypt. The dates are said by Delchevalerie to be made up into a paste and eaten by the inhabitants of that part of Egypt. See S. P. I. No. 6438." (Walter T. Swingle.)

32718. "*Siri*."

32720. "*Bartamoda*."¹

32719. "*Adel Malakawi*."¹

32721. "*Amhat*. As to this variety there seems to be much confusion in the Egyptian literature, several varieties being undoubtedly confounded under the same name. Until the dates fruit it will be difficult to tell more about them." (Walter T. Swingle.)

32722. "*Zagloul*." See No. 6439 for description.

32723. "*Bint Aischa*." See No. 6440 for description.

32724. "*Amari*. Perhaps the same as *Amri* (S. P. I. 6445). The name would indicate a red date, which is a common date in Lower Egypt, frequently exported to Europe in a dry condition." (Walter T. Swingle.)

32725. "*Samany*." See No. 6441 for description.

32726. CITRUS sp.

From Hangchow, China. Presented by Mrs. J. H. Judson, Hangchow College. Received February 7, 1912.

32728. PROSOPIS STEPHANIANA (Bieb.) Kunth.

From Ayaba, Oued Rh'ir, south of Biskra, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received February 8, 1912.

"Grows on alkaline deserts." (Trabut.)

See No. 29996 for previous introduction.

32729. ARALIA CALIFORNICA S. Watson. California spikenard.

From California. Procured by Mr. G. P. Rixford, of the Bureau of Plant Industry, stationed in San Francisco. Received February 7, 1912.

Procured for breeding purposes. See No. 32169 for description.

32730. NITRARIA SCHOBERI L.

From Spencers Gulf, South Australia. Presented by Prof. J. H. Maiden, Director, Royal Botanic Garden, Sydney, New South Wales, Australia. Received February 8, 1912.

The following notes were written by Prof. Maiden, while standing opposite plants of *Nitraria schoberi* at Port Augusta at the northern end of Spencers Gulf, South Australia.

"Fruits the size of a small cherry with a narrowish, grooved stone. Very fleshy, translucent, and of a reddish brown color, remarkably like a Kentish cherry. Not at all bad eating, with a slight bitter flavor, not at all unpleasant."

32731. CHAETOCLOA MAGNA (Griseb.) Scribn. Wild millet.

From Millstone, Md. Collected by Mr. Ivar Tidestrom, of the Bureau of Plant Industry, September 1, 1911. Received February 8, 1912.

"This species, a large succulent annual, resembles the cultivated foxtail millet. It grows among shrubs and high herbs or in the open in mucky soil along the coast from Maryland southward. I am unable to say whether or not it can be grown in ordinary field soil, but it seems worthy of trial." (A. S. Hitchcock.)

¹ "Drying dates from Upper Egypt." (Aaronsohn.)

32733 to 32747. PYRUS COMMUNIS L.**Pear.**

From Collegeville, Minn. Presented by Rev. John B. Katzner, Superintendent, Trial Station, Minnesota State Horticultural Society, Collegeville. Received October, 1911. Numbered February 9, 1912.

Cuttings of the following varieties of pears, procured from Germany by Mr. Katzner; quoted notes by him:

- 32733.** "*Madam Favre*. A vigorous grower and a prolific bearer. Fruit large, of very good quality, suitable for dessert. Ripens in September."
- 32734.** "*Schoene Julie*. A prolific tree of good growth. Small fruit, very good quality, useful for dessert. Ripens in October."
- 32735.** "*Herzogin Elsa*. A prolific variety of good growth. Large fruit, very good quality, suitable for dessert. Ripens in September."
- 32736.** "*Beuckes Butterbirne*. A vigorous grower. Fruit, medium, very good quality, useful for dessert. Ripe in September."
- 32737.** "*Gute Louise von Avranches*. A very vigorous and prolific variety. Quite large fruit, very good to excellent quality, suitable for dessert. Ripe in October."
- 32738.** "*Magdalenebirne*. Vigorous and very prolific. Small fruit of very good quality, suitable for dessert. Ripe from July to August."
- 32739.** "*Gellerts Butterbirne*. A vigorous and very prolific variety. Large fruit of very good to excellent quality, which may be used for dessert."
- 32740.** "*Triumph von Viennes*. A vigorous and prolific variety. Fruit is one of the largest grown. It is of very good quality and is suitable for dessert. Ripe from September to October."
- 32741.** "*Amanlis Butterbirne*. Vigorous and very prolific. Large fruit of very good to excellent quality, suitable for dessert. Ripens in September."
- 32742.** "*Kuettelbirne*. Fruit ripe from November to January. Can be used for dessert and for cooking."
- 32743.** "*Philipp's Birne*." Same description as for No. 32735.
- 32744.** "*Trockener Martin*. Tree of good growth and very prolific. Small fruit which is very good for cooking. Ripe from December to March."
- 32745.** "*Baronsbirne*. A good bearer and grower. Large fruit, the very best for cooking purposes. Fruit ripe from January to April."
- 32746.** "*Hofratsbirne*. A very vigorous variety. Fruit large, of very good to excellent quality, suitable for dessert. Ripe from October to November."
- 32747.** "*Englische Sommerbirne*. A vigorous grower and prolific bearer. Fruit very good, useful for dessert. Ripens in September."

"All the above varieties I have tried. While they are not hardy with us, they showed no signs of blight and therefore may be very good for other parts in the United States, as in Michigan, eastern Wisconsin, and Eastern and Western States."

32748 and 32749. DIOSPYROS KAKI L. f.**Persimmon.**

From Sapporo, Japan. Presented by Mr. Y. Takahashi, botanist and vegetable pathologist, Hokkaido Agricultural Experiment Station. Received February 10, 1912.

Cuttings of the following:

- 32748.** Variety *Hachiya*. Japanese name *Ko shikaki*.
- 32749.** Variety *Hiyakume*. Japanese name *Hiyakume kaki*.

32750. DIOSPYROS KAKI L. f.**Persimmon.**

From Kawanishimura, Settsu, Japan. Presented by Mr. M. Kishimoto, Japan Nursery Co. (Ltd.) Received February 12, 1912.

"Scions from male persimmon trees." (*Kishimoto*.)

32751. PRUNUS sp.**Prune.**

From Langenbuhl, Thun, Berne, Switzerland. Presented by Mr. Felix Wenger. Received February 12, 1912.

Quoted note by Mr. R. Wenger, of Newberg, Oreg., who suggested the procuring of this prune.

"This prune resembles the Italian, but is much larger and contains more sugar. It is locally known as the 'grafted prune.' I have had considerable experience in prune growing in this State, and I am confident that if this prune would do as well here as it did at Langenbuhl, it would be of great benefit to the entire Northwest."

32752. FICUS ROXBURGHII Wallich.**Fig.**

From Sibpur, Calcutta, India. Presented by Maj. A. T. Gage, Director, Royal Botanic Garden. Received February 12, 1912.

Distribution.—A middle-sized tree found on the lower slopes of the Himalayas in northern India, rising to an elevation of 6,000 feet and extending from the Province of Assam to the valley of the Indus River.

32753. PUNICA GRANATUM L.**Pomegranate.**

From Raleigh, N. C. Presented by Mr. William J. Andrews. Received February 10, 1912.

"Skin greenish yellow, with no red color, moderately thick. Dissepiment broad-triangular. Grains medium large, obovoid, beautifully carmine colored. Seeds large and hard. Very juicy and acid (too much so for eating without sugar). Large fruit well adapted for making sherbets, etc." (*T. H. Kearney*.)

32757 to 32774.

From Russia. Received through Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry, February 16, 1912.

Seeds of the following:

32757. PRUNUS sp.**Plum.**

This and the next lot of seed were received under the name *Prunus ussuriensis*, but as yet the place of publication of this name has not been found.

From Souchodole, Tula Government, Russia.

"(No. 1727a, December 30, 1911.) A wild plum, from the Usuri district, eastern Siberia. Said to be of large size, red in color, and an early ripener. Considered to improve in flavor by being frozen. Obtained from Mr. D. D. Kashgaroff at Souchodole. Will probably thrive better in the eastern sections of the United States than in the Middle West." (*Meyer*.)

32758. PRUNUS sp.**Plum.**

From Souchodole, Tula Government, Russia.

"(No. 1728a, December 30, 1911.) A variety of wild plum coming from the Usuri district, eastern Siberia. Said to be of medium size and of a yellow color. Obtained like the preceding number." (*Meyer*.)

32757 to 32774—Continued.

32759. *PRUNUS PADUS* L.

Cherry.

From Souchodole, Tula Government, Russia.

“(No. 1729a, December 30, 1911.) A small-fruited species from the Usuri district, eastern Siberia. Grows in the jungle. Said to bear edible fruits. Obtained like the preceding number.” (Meyer.)

32760. *AMYGDALUS NANA* L.

From Kozlov, Tambov Government, Russia.

“(No. 1730a, December 28, 1911.) A form of almond obtained from Mr. I. V. Mijurin at Kozlov; possibly a hybrid.” (Meyer.)

32761. *RIBES MEYERI* Maxim.

Currant.

From Souchodole, Tula Government, Russia.

“(No. 1731a, December 30, 1911.) Variety *turkestanica*. A black currant coming from Russian Turkestan. Said to bear unusually large, fine-flavored fruits. Obtained from Mr. D. D. Kashgaroff at Souchodole.” (Meyer.)

32762. *RIBES PROCUMBENS* Pallas.

Currant.

From Souchodole, Tula Government, Russia.

“(No. 1732a, December 30, 1911.) A species of currant called *Markakulskaia smarodnaia* from the Marka Kul region, Altai Mountains, southwestern Siberia. Said to bear berries of a brownish black color as large as cherries. Occurs on moist, cool places and apparently objects to drought and heat. To be tested in southern Alaska and in the moist, elevated regions of the United States. Obtained like the preceding number.” (Meyer.)

Distribution.—The province of Dauria in eastern Siberia.

32763. *CLEMATIS TANGUTICA* (Maxim.) Korsh.

Clematis.

From Kozlov, Tambov Government, Russia.

“(No. 1733a, December 28, 1911.) An ornamental, climbing, woody clematis, bearing large, yellow flowers. Has proved to be perfectly hardy in central Russia. Obtained from Mr. I. V. Mijurin, who stated that he had received the seeds from Tibet.” (Meyer.)

Distribution.—On the slopes of the mountains at an elevation of 11,000 to 13,000 feet in Tibet and Mongolia.

32764. *LILIUM MONADELPHUM* (var. *SZOWITSIANUM*) × *ELEGANS*.

From Kozlov, Tambov Government, Russia.

“(No. 1734a, December 28, 1911.) A lily originated by Mr. I. V. Mijurin at Kozlov; bears flowers of a deep-yellow color and is extraordinarily floriferous; apparently of great promise as an ornamental perennial for the hardy border. Bulbs of this hybrid are stated by Mr. Mijurin to weigh up to 6 pounds a piece.” (Meyer.)

32765. *TRITICUM AESTIVUM* L.

Wheat.

From Kharkof, Russia.

“(No. 1735a, December 22, 1911.) A variety of bearded winter wheat called *Krasny oristaia*, much grown in southern Russia. Gives an abundant crop and stands winter cold and summer heat better than most other varieties. Obtained from Mr. P. V. Budrin, Director of the Kharkof Selection Station.” (Meyer.)

32757 to 32774—Continued.

32766. TRITICUM AESTIVUM L.

Wheat.

From Kharkof, Russia.

"(No. 1736a, December 22, 1911.) A variety of beardless winter wheat, called *Krassny besostia*, extensively grown in southern Russia and possessing much the same qualities as the preceding number. Obtained from the same source." (Meyer.)

32767. HORDEUM VULGARE L.

Barley.

From Rostov, Russia.

"(No. 1737a, December 19, 1911.) A new variety of black summer barley, called *Chorny gladko-osti*. First found at the agricultural experiment station in Taganrog, southern Russia. This is a decided improvement on the ordinary barleys with their hooked awns, which make them especially objectionable for feeding purposes. Obtained at the agricultural experiment station near Rostov, through Mr. S. M. Groobnieff, Secretary of the Don-Kuban-Tersk Agricultural Society. This barley seems to do well in regions with rather high summer temperatures and where there is only a relatively light precipitation. To be used exclusively for breeding purposes." (Meyer.)

32768. PANICUM MILIACEUM L.

Millet.

From Kharkof, Russia.

"(No. 1738a, December 22, 1911.) A variety of millet called *Chorny proso*. It has large, black seeds and is a medium-early ripener. In Kharkof it is considered to be the best variety. Obtained from Mr. P. V. Budrin, Director of the Agricultural Selection Station at Kharkof." (Meyer.)

32769. HELIANTHUS ANNUUS L.

Sunflower.

From Rostov, Russia.

"(No. 1739a, December 19, 1911.) A variety of sunflower called *Zelenka*, which has large, plump seeds, is cultivated for oil production exclusively, and is specially recommended as being more resistant to the ravages of orobanches than the ordinary varieties. Obtained like No. 1737a (S. P. I. No. 32767)." (Meyer.)

32770. PISUM SATIVUM L.

Pea.

From Moscow, Russia.

"(No. 1740a, January 10, 1912.) A tall-growing sugar pea, said to be a prolific bearer, with seeds that swell out in cooking and have a meaty flavor. Called *Merzeimski*, probably derived from the German name 'Meerheim.' Purchased in Moscow." (Meyer.)

32771. PISUM SATIVUM L.

Pea.

From Moscow, Russia.

"(No. 1741a, January 10, 1912.) A variety of garden pea called *Chorny-piati*; has black eyes. Said to be of tall growth and of ordinary quality. Purchased in Moscow." (Meyer.)

32772. PISUM SATIVUM L.

Pea.

From Moscow, Russia.

"(No. 1742a, January 4, 1912.) A variety of garden pea obtained from the originator, Mr. D. von Roodzinski, in charge of the Selection Station near Moscow; called by him *Stambovi-Petrowska-Razumowski*. An erect grower with fasciated stem. Is a prolific bearer; the flowering period is confined to

32757 to 32774—Continued.

four or five days, which results in uniform maturing of the crop. Mr. Roodzinski stated that this variety is 65 per cent more productive than the ordinary varieties of garden peas. Will apparently be of special value for the more northern regions of the United States. Mr. Roodzinski's number for this variety is 576." (*Meyer.*)

32773. LINUM USITATISSIMUM L.**Flax.**

From Moscow, Russia.

"(No. 1743a, January 4, 1912.) A variety of flax selected by Mr. D. von Roodzinski at Moscow for four years. A very tall, erect grower reaching a height of 105 centimeters [41 inches] in height. Called *Pasowski flax* No. 802. Obtained from the originator." (*Meyer.*)

32774. CITRULLUS VULGARIS. Schrad.**Watermelon.**

From Moscow, Russia.

"(No. 1744a, January 10, 1912.) A watermelon called *Monastirski arboos* said to be much grown in southern Russia as a market variety. Is round in shape and of medium size; has thin skin, light green in color, with dark encircling bands; the flesh is red and of very sweet taste; it is a medium-early ripener. Purchased in Moscow." (*Meyer.*)

32775 and 32776. POPULUS spp.**Poplar.**

From Slottaskogen, Gothenburg, Sweden. Received through Mr. Stuart J. Fuller, American consul, February 17, 1912.

Cuttings of the following:

32775. POPULUS TREMULA L.

See No. 30577 for previous introduction.

32776. POPULUS NIGRA L.

See No. 30055 for previous introduction.

32777 to 32783.

Procured by Mr. C. V. Piper, of the Bureau of Plant Industry. Received February 16, 1912.

Seeds of the following; quoted notes by Mr. Piper:

32777. CRACCA VILLOSA PURPUREA (L.) Kuntze.

"From the botanical gardens, Buitenzorg, Java. A legume that is being experimented with at the Buitenzorg garden as a green-manure crop. It possesses considerable promise for this purpose."

Distribution.—Throughout the plains of India, and generally scattered in the Tropics.

32778. CRACCA VILLOSA ARGENTEA (Lam.) Kuntze.

"A large, half-shrubby species, which is being experimented with at the Buitenzorg Botanic Garden, as a green-manure crop."

32779. MEIBOMIA PARVIFOLIA (DC.) Kuntze.

From Buitenzorg, Java.

"A legume, which closely resembles in appearance the Florida beggarweed and is probably of similar value."

Distribution.—Throughout the plains of India from the Himalayas, where it ascends to an elevation of 7,000 feet, to Ceylon, and eastward to China and Japan, and in the Malay Archipelago.

32777 to 32783—Continued.

32780. *BRADBURYA PUBESCENS* (Benth.) Kuntze.

"A leguminous vine being experimented with at Buitenzorg, Java, as a green-manure crop. It has much the habit of *Bradburya plumieri*."

32781. *APOCOPIS* sp.

"An unknown grass growing in the garden at Buitenzorg, Java, from seed collected in New Guinea. It apparently has considerable promise as a pasture grass for the extreme southern States."

32782. *INDIGOFERA LINIFOLIA* (L. f.) Retz.

From Pusa, India.

"An annual legume abundant throughout the upper Ganges Valley, and also in the Bombay Presidency, India. In some sections it is considered one of the best native legume varieties. It should succeed well under southern California conditions."

32783. *ZORNIA DIPHYLLA* (L.) Pers.

From Bangalore, India.

"An annual legume found throughout the upper Ganges Valley and in the Bombay Presidency, and of similar value to the preceding number."

32784 to 32826.

From Seharunpur, India. Presented by Mr. A. C. Hartless, Superintendent, Government Botanic Gardens, at the request of Mr. C. V. Piper of the Bureau of Plant Industry. Received February 8, 1912.

Seeds of the following; quoted notes by Mr. Piper:

32784. *ANDROPOGON HALEPENSIS* (L.) Brot.

"This is the variety of *Andropogon halepensis* common throughout the Ganges Valley. It is quite different from the ordinary variety of Johnson grass introduced into this country, having a much larger, looser, drooping panicle, but also having the same development of rootstocks and being equally weedy. It should be tested with care."

32785. *ARTEMISIA* sp.

This was received under the name *Artemisia jacobumviridis*, but as yet the place of publication of this name has not been found.

32786. *BAUHINIA PURPUREA* L.

"Very similar to *Bauhinia variegata* (S. P. I. No. 32787), but the flowers are red."

Distribution.—A medium-sized tree found in India from the foot of the western Himalayas to Ceylon, and eastward to China.

32787. *BAUHINIA VARIEGATA* L.

"A small tree, with butterfly-shaped leaves, and showy white flowers."

Distribution.—A tree found throughout India from the western Himalayas to Burma, and eastward to China.

32788. *BELOU MARMELOS* (L.) Lyons.

Bael.

32789. *BERBERIS ARISTATA* DC.

Barberry.

32790. *BISCHOFIA JAVANICA* Blume.

"What has been identified as this same species seems to have been introduced into Florida some time ago, and at Oneco there is a beautiful specimen which, although injured during the great freezes, has recovered and is now a very beautiful shade tree." (*David Fairchild*.)

32784 to 32826—Continued.

Distribution.—A roundheaded tree found in India from the tropical slopes of the Himalayas in Kumaon eastward and southward through the hills of the Dekkan Peninsula, and from Assam to Tenasserim, and in the Malay Archipelago and the Pacific Islands.

32791. *BOMBAX MALABARICUM* DC. Red silk-cotton tree.

32792. *BUTEA MONOSPERMA* (Lam.) Taub.

"A leguminous tree with very handsome foliage and producing a great abundance of orange-scarlet blossoms. It is deciduous, grows 30 to 35 feet high, and is rather wide spreading."

32793. *CALAMUS TENUIS* Roxburgh. Rattan.

"One of the rattan palms."

Distribution.—A climbing palm found on the tropical slopes of the Himalayas from Kumaon eastward and southward through Bengal, Assam, Chittagong, and Sylhet to Burma, and extending to Cochin China.

32794. *CALLICARPA MACROPHYLLA* Vahl.

Distribution.—A shrub with wandlike branches and white berries, found in the northern and eastern parts of India

32795. *CALLISTEMON CITRINA* (Curtis) Skeels.

(*Metrosideros citrina* Curtis 1794, Botanical Magazine, vol. 7, pl. 260.)

The seeds of this ornamental myrtaceous shrub from Australia were received under the name *Callistemon lanceolatum* DC. 1823 (Prodromus, vol. 3, p. 223) which was based on *Metrosideros lanceolata* J. E. Smith 1797 (Transactions of the Linnean Society, vol. 3, p. 272). Dr. Smith cited "*M. citrina*. Curt., Mag. t. 260," and remarked in part as follows: "I would never change a name that has been generally in use, whether published or not; but this is too preposterous to be retained." As the present rules of botanical nomenclature require the retaining of the first specific name applied to a species, Curtis's name is here restored.

Callistemon citrina is found along streams and near the coast of the eastern part of Australia in Queensland, New South Wales, and Victoria.

32796. *CASSIA* sp.

32797. *CELTIS AUSTRALIS* L.

"A very splendid shade tree, growing to a height of 40 feet. It has a shapely crown, and the branches are somewhat pendulous. It is said to be a rapid grower."

Distribution.—A variable tree found in southern Europe, northern Africa, and eastward in Asia to India.

32798. *CINNAMOMUM CAMPHORA* (L.) Nees and Eberm. Camphor.

32799. *DIOSPYROS MONTANA* Roxb.

"A small, erect, deciduous tree, growing to a height of about 30 feet. Is quite ornamental and useful where small trees are desirable."

32800. *DIOSPYROS PEREGRINA* (Gaertn.) Guerke.

"A vigorous species growing about 30 feet high with a dense, spreading habit. The round russet-colored fruits are very attractive, but are not eaten. These make a beautiful contrast with the bright glossy-green leaves."

32801. *DURANTA REPENS* L.

"A shrub growing to a height of 6 or 8 feet and covered with white or lavender flowers in drooping racemes, followed by an abundance of orange-colored

32784 to 32826—Continued.

berries. Frequently the bush bears blossoms and fruits at the same time. It also makes excellent hedges."

Distribution.—A small tree or shrub found in sandy soil in southern Florida, in the West Indies, and from Orizaba in Mexico southeastward to Peru and Brazil.

32802. *EHRETIA ACUMINATA* R. Br.

"A deciduous tree, rather dwarf, producing white flowers in abundance."

32803. *ERYTHRINA VESPERTILIO* Benth. Heilaman tree.

Distribution.—A shrub or low tree found along streams in North Australia and Queensland.

32804. *EUCALYPTUS SALIGNA* Smith.

Couranga.

Distribution.—A tall tree with smooth, silver-gray, shining bark, found along streams in New South Wales, Australia.

32805. *FIGUS LUCESCENS* Blume.

"A deciduous species, with compact habit, growing to a height of about 30 to 35 feet. It is said to grow very rapidly. Leaves bright glossy green."

Distribution.—A low tree found on the plains and lower hills of India and eastward through the Malay Archipelago to Java.

32806. *FIGUS RELIGIOSA* L.

Pipal.

"The peepul tree. One of the most generally grown shade trees throughout India, is quite hardy, and is grown far north into the Punjab region. While it thrives best under moist conditions, it will nevertheless withstand much drought."

Distribution.—A tree found in the lower Himalayan forests in Bengal, and in central India; generally planted in India and Ceylon and the Malay Archipelago.

32807. *GLEDITSIA FEROX* Desf.

Distribution.—A tree with stiff, straight spines, found in the northern part of China; often cultivated as an ornamental.

32808. *GMELINA ARBOREA* Roxburgh.

"Native name *Khumbur*. Considerably grown as a shade tree in the upper Ganges Valley. Deciduous, growing 40 to 50 feet high, and with a round, compact crown. It should do well in southern California."

Distribution.—A large tree bearing dull-yellow flowers in panicles, found throughout India from the base of the Himalayas southward and eastward, and extending through the Malay Archipelago to the Philippines.

32809. *HETEROPHRAGMA ADENOPHYLLUM* (DC.) Seem.

"A very handsome shade tree with abundant yellow blossoms; much grown at Lucknow."

Distribution.—A medium-sized tree with stout panicles of large yellowish brown flowers, found in the eastern part of India, extending from eastern Bengal and Assam southward through Burma to Tenasserim and the Andaman Islands.

32810. *HOLARRHENA ANTIDYSENTERICA* (Roth) Wall.

Conessi.

Distribution.—A small tree found on the tropical slopes of the Himalayas and throughout the drier forests of India.

32784 to 32826—Continued.

32811. *HOLOPTELEA INTEGRIFOLIA* (Roxb.) Planchon. Indian-elm.

Distribution.—A large, spreading tree found in India from the lower ranges of the Himalayas southward and eastward to Ceylon and Cochin China.

32812. *KYDIA CALYCINÁ* Roxburgh.

Distribution.—A tree with large panicles of white or pink flowers, found in India from the tropical slopes of the Himalayas in Kumaon eastward to Burma and southward to the Coromandel Coast.

32813. *LAGERSTROEMIA PARVIFLORA* Roxburgh.

Distribution.—A tree with small white flowers found in India from the base of the western Himalayas southward throughout the Dekkan Peninsula.

32814. *LAGERSTROEMIA SPECIOSA* (L.) Persoon.

"A beautiful tree cultivated throughout India, producing a great abundance of beautiful purple flowers. It is closely related to the crape myrtle of the South, but the flowers are much larger and handsomer. It should succeed in Florida and southern California."

32815. *LANTANA* sp.

32816. *LEUCAENA GLAUCA* (L.) Benth.

32817. *NYCTANTHES ARBOR-TRISTIS* L.

Hursingar.

"A dwarf tree with spreading top and highly scented white flowers."

Distribution.—A small tree with flowers in heads, found in India at an elevation of 1,000 to 3,000 feet; generally cultivated in the Tropics.

32818. *OROXYLON INDICUM* (L.) Vent.

See No. 29183 for description.

32819. *OWENIA CERASIFERA* F. Mueller.

Queensland-plum.

"A handsome evergreen tree; the fruit is eaten."

Distribution.—A small tree growing along the Burdekin River in Queensland, Australia.

32820. *PARKINSONIA ACULEATA* L.

32821. *PHOENIX FARINIFERA* Roxburgh.

"The leaves of *Phoenix farinifera* are made into coarse sleeping mats in India, while the split petioles are fashioned into baskets. In China the fiber is used for brushes." (*Dodge, Useful Fiber Plants.*)

"A dwarf species, adapted to sandy and otherwise dry and barren land, but prefers the vicinity of the sea. Berry shining black, with a sweet mealy pulp." (*Mueller, Select Plants.*)

Distribution.—Along the Coromandel Coast of southern India, and in the northern part of Ceylon.

32822. *PHOENIX PALUDOSA* Roxburgh.

"A stout Indian species, not very tall, of value for decorative culture." (*Mueller, Select Plants.*)

"The leaves supply material for rough ropes in the Sundarbans, which are used for securing boats, logs, etc., and its leaves are also employed for thatching." (*Dodge, Useful Fiber Plants.*)

Distribution.—A small tree found at the mouths of rivers along the coast of India from Bengal to Burma and in the Andaman Islands; also in Siam and Cochin China.

32784 to 32826—Continued.

32823. PHOENIX ZEYLANICA Trimen.

A moist low-growing species occurring in Ceylon, attaining a height of from 6 to 20 feet, and much resembling *Phoenix sylvestris*.

Distribution.—A small tree growing in the southern and western parts of Ceylon.

32824. PHYLLANTHUS EMBLICA L.

Emblie myrobalan.

32826. TOONA CILIATA Roemer.

"Toon tree."

"A splendid, rapidly growing shade tree much grown in northern India. It produces excellent timber."

32827 and 32828. PISTACIA VERA L.

Pistache.

From Russian Turkestan. Purchased from Mr. Vladimir F. Gnesin, Tashkend. Received February 16, 1912.

Seeds of the following; quoted notes by Mr. Gnesin:

32827. "From north of Andijan about 60 miles. From Isbo kent north 38 miles. Altitude about 4,000 feet."

32828. "From east northeast of Andijan near Tcharvok. Altitude about 3,000 feet."

32829 to 32836.

From Imperial Estate "Murgab," Bairam-Ali, Oasis of Merv, Russian Turkestan. Received through Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry, February 19, 1912. Collected by him in November, 1911.

Trees of the following; quoted notes by Mr. Meyer:

32829. ULMUS DENSE Litvinov.

Elm.

"(No. 997.) An ornamental elm, forming a dense head of branches, which are often clothed with corky wings. Stands great heat and a fair percentage of alkaline matter in the soil. Bears the name of *Stamboul*, implying, perhaps, that it came from Constantinople."

Distribution.—The province of Bokhara in the southern part of Turkestan.

32830. ULMUS DENSE Litvinov.

Elm.

"(No. 998.) An ornamental elm, much like the former, but not of as strong growth. Head globular when young, but as it grows older it loses this regularity of outline and often requires a large space to come to full maturity. This variety is locally called *Kizisky*, implying that it came from China." (Meyer.)

32831. ULMUS sp.

Elm.

"(No. 999.) A variety or perhaps a species of elm called *Charavindy*. It is of remarkably dense growth, sprouting out a little distance above the ground, into a number of stems, which form an umbrellalike head of foliage, which is so dense that it seems always twilight, even at bright noon, in an avenue of these trees. This elm apparently prefers a climate with long, hot summers and winters not too cold. It withstands a fair amount of alkali in the soil and in the irrigation water and would be of special value as a shade tree in the hot and dry interior valleys of California, in Arizona, Texas, and New Mexico." (Meyer.)

Note: "The Turki name for elm is *Karagatch* or *Karayagatch*, meaning black wood. The Russians in Turkestan, however, have come to give the name *Karagatch* exclusively to the roundheaded, densely growing varieties of elms." (Meyer.)

32829 to 32836—Continued.**32832. PRUNUS ARMENIACA L.****Apricot.**

"(No. 1000.) A native central Asian variety, called *Bjelvia Zvezda*, meaning white star. Originated in the oasis of Samarkand. Fruits large, of pale-yellow color, very aromatic." (*Meyer*.)

32833. PRUNUS ARMENIACA L.**Apricot.**

"(No. 1002.) A native central Asian variety of apricot, called *Beiram-Ali*. Said to be of excellent qualities." (*Meyer*.)

32834. PRUNUS ARMENIACA L.**Apricot.**

"(No. 1001.)" Cuttings of this received under S. P. I. No. 32348. See this number for description.

32835. PRUNUS ARMENIACA L.**Apricot.**

"(No. 1003.)" Cuttings of this received under S. P. I. No. 32349. See this number for description.

32836. PRUNUS ARMENIACA L.**Apricot.**

"(No. 1004.)" Cuttings received under S. P. I. No. 32350. See this number for description.

32837. LANGUAS GALANGA (L.) Stuntz.**Galangale.**

From the island of Cebu. Presented by Mr. O. W. Barrett, Chief, Division of Experiment Stations, Bureau of Agriculture, Manila, P. I. Received February 19, 1912.

"This root is used in place of ginger, or perhaps in preference thereto. The plant is known in the Visayas as *Languas* and as *Lancoas* in Pampanga, Luzon; it is only semicultivated anywhere. It is used both raw and cooked with fish and meats." (*Barrett*.)

32840 and 32841.

From Mexico. Presented by Dr. C. A. Purpus, Zacuapam, Huatusco, Vera Cruz, Mexico. Received February 19, 1912.

Seeds of the following; quoted notes by Dr. Purpus:

32840. PEDILANTHUS APHYLLUS Boiss.

"Wax plant from Tehuacan, Puebla."

32841. PINUS GREGGII Engelm.**Pine.**

"From Esperanza, Puebla."

32842. PERSEA AMERICANA Miller.**Avocado.**

From Guatemala City, Guatemala. Presented by Mr. Geo. A. Bucklin, jr., American consul general. Received February 20, 1912.

"Seeds of the round variety from Amatitlan."

32843 and 32844.

From Manila, Philippine Islands. Presented by Mr. O. W. Barrett, Chief, Division of Experiment Stations, Bureau of Agriculture. Received February 20, 1912.

"Roots of the following plants which are found in comparatively moist situations and in half shade; should prove desirable ornamentals." (*Barrett*.)

32843. (Undetermined.)**Aroid.****32844. (Undetermined.)**

"A zinziberaceous plant that reaches a height of 10 to 15 feet." (*Barrett*.)

32845 to 32859. PHOENIX DACTYLIFERA L.**Date.**

From Gourara, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria, at the request of Mr. Walter T. Swingle, of the Bureau of Plant Industry. Received February 19, 1912.

Fruits of the following; notes by Dr. Trabut:

- 32845. *Timedouel*. From the oasis of Oulad Said.
- 32846. *Timoudjedel*. From the oasis of Oulad Said.
- 32847. *Tinakorr*. From the oasis of El Barka.
- 32848. *Tinhoud*. From the oasis of Heha.
- 32849. *Fillal*. From the oasis of Adjediral.
- 32850. *Adham el Hejd*. From the oasis of El Barka.
- 32851. *Tazerzait*. From the oases of Timimoun and Oulad Said.
- 32852. *Takarouchett*. From the oasis of Timimoun.
- 32853. *Tinasser*. From the oasis of Heha.
- 32854. *Ahartann*. From the oasis of Timimoun.
- 32855. *Tinaassou*. From the oasis of Oulad Said.
- 32856. *Timdjouhart*. From the oasis of Timimoun.
- 32857. *Timleah*. From the oasis of Timimoun.

Note: Name on sack containing these fruits was *Timleha*.

- 32858. *Tilemson*. From the oasis of Timimoun.
- 32859. *Degla*. From the oasis of Taghouzi.

32860. PRUNUS PSEUDO-CERASUS Lindl.**Japanese flowering cherry.**

From Yokohama, Japan. Purchased from the Yokohama Nursery Co. Received February 19, 1912.

Seeds of the flowering cherry from the island of Oshima, for use in experiments to find a suitable stock for the double-flowered varieties.

32863. DIOSPYROS LOTUS L.**Wild persimmon.**

From Tangai, China. Presented by Rev. Alex. Kennedy, through Rev. J. M. Farnham, Shanghai, China. Received February 14, 1912.

Cuttings.

32864 to 32866. DIOSPYROS KAKI L. f.**Persimmon.**

From Hiroshima, Japan. Purchased from Rev. H. Loomis, Yokohama. Received February 23, 1912.

Cuttings of the following; names and notes by Rev. Mr. Loomis:

- 32864. "*Gumbo*. Supposed to be scions of this variety, which is considered the best in Japan for drying."
- 32865. "*Saijo*."
- 32866. "*Gusho*."

32867 to 32872. DIOSPYROS KAKI L. f.**Persimmon.**

From Kawanishimura, Settsu, Japan. Presented by Mr. M. Kishimoto, Japan Nursery Co. (Ltd.). Received February 24, 1912.

Plants of the following; quoted notes by Mr. Kishimoto:

- 32867. "*Gusho*. Shape flat, taste sweet."

32867 to 32872—Continued.

32868. "*Fuyu*. Large, sweet variety."

32869. "*Mino*. Very large, astringent variety."

32870. "*Kubo*. Very early, sweet variety."

32871. No label.

32872. No label.

NOTE.—These two unlabeled plants are *Kubo*, listed under S. P. I. No. 32870, and *Hachiya*, a long, astringent variety. They can probably be identified when they fruit.

32873. MAURITIA VINIFERA Mart.**Buriti.**

From Bahia, Brazil. Presented by Mr. Southard P. Warner, American consul.

Received February 27, 1912.

"A beautiful palm, which I saw in the greatest abundance in the swamps of Piahy and Goyaz; it is called *Buriti* by the inhabitants, and is the *Mauritia vinifera* of Martius. This plant is not only the most beautiful, but one of the loftiest in the country; the leaves are fan shaped and form a large round ball at the top of the stem, after the manner of the *Carnahuba*. It produces a great number of nuts about the size of a small egg, covered with rhomboidal scales arranged in a spiral manner; between these scales and the albuminous substance of the nut there exists an oily pulp of a reddish color, which the inhabitants of Crato boil with sugar and make into a sweetmeat. In Piahy they prepare from this pulp an emulsion which, when sweetened with sugar, forms a very palatable beverage, but if much used it is said to tinge the skin a yellowish color. The juice of the stem also forms a very agreeable drink, but to obtain it the tree must be cut down, when several holes about 6 inches square, 3 deep, and about 6 feet apart are cut in the trunk with a small axe, which in a short time become filled with a reddish colored liquid having much the flavor of sweet wine." (*G. Gardner, Travels in the Interior of Brazil, p. 171-172.*)

32874. PERSEA AMERICANA Miller.**Avocado.**

From Guatemala City, Guatemala. Presented by Mr. S. Billow. Received February 26, 1912.

"Seeds of an avocado stated to be the largest and most deliciously flavored variety that is grown in Guatemala. They are now (February 22) in season." (*Billow.*)

32875. CITRUS NOBILIS Lour.(?)**Tangerine.**

From Algiers, Algeria. Presented by Dr. L. Trabut. Received February 26, 1912.

"*Clementine.*"

Cuttings.

32877. TRITICUM DURUM Desf.**Wheat.**

From Atbazar, Akmolinsk district, Siberia. Received through Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry. Received February 27, 1912.

"(No. 1745a, November, 1911.) A very large hard wheat, called *Afrikanski*. Obtained through Mr. E. H. Brittenham, assistant manager of the Omsk office of the International Harvester Co. of America. See No. 1631a (S. P. I. No. 32175) for further remarks." (*Meyer.*)

32878 to 32882.

From Granada, Spain. Received from Mr. Pedro Giraud, at the request of Mr. William A. S. Davenport, British consulate, February 26, 1912.

Cuttings of the following; quoted notes by Dr. Gustav Eisen, Academy of Sciences, San Francisco, Cal.:

32878. *FICUS CARICA* L.

Fig.

"*Isabella*. This is cultivated extensively, I might say preferably, in and about Granada. It is a medium-sized fig, rounded turbinate, white in color, with reddish pulp. In shape it resembles the *Ficus hirta* of Japan, with a well set neck. It is an exceedingly good fig and one of the best table varieties I have tasted. It was ripe in September and we still had good fruit in November, a long season for any fig. This fig, as far as I know, has not been introduced in California."

32879. *VITIS VINIFERA* L.

Grape.

"*Jeresiana*. This is the predominant grape in Granada. It resembles the *Verdal* as grown in California, but is sweeter, though perhaps smaller in size. Its pulp is firm and stands shipment well, the large, white bunches apparently as perfect after having stood the transportation over country roads as if they had just been picked from the vine. It is a very desirable table variety and one which seems suited to a high altitude. It is also a good bearer, a hardy plant, and altogether a profitable grape. I have not observed it in California."

32880. *OLEA EUROPEA* L.

Olive.

"*Cuatro hermanos*, from Canales. These olives are of good size and early maturity, ripening in November. They occur always in fours, sitting close together and forming a cross with four arms on the very stem. It is said to be one of the best olives for both oil and pickling. The olive from this locality is considered one of the hardest and is suited to districts situated on the limits of possible olive culture, Canales being about 4,000 feet above Granada and 6,000 above sea level, and subject to heavy winds, heavy frosts, and winter snows. Still, olive culture is profitable around Canales and every available space of ground is covered with trees."

32881. *PUNICA GRANATUM* L.

Pomegranate.

"*Granados de la Vega*."

32882. *CYDONIA OBLONGA* Miller.

Quince.

"From Antequera, said to be the best."

32883 and 32884.

From Spain. Received from Mr. Pedro Giraud, at the request of Mr. William A. S. Davenport, British consulate, Granada, February 26, 1912.

Seeds of the following; quoted notes by Dr. Gustav Eisen, California Academy of Sciences, San Francisco, Cal.:

32883. *CUCUMIS MELO* L.

Muskmelon.

"*San Martin*. This is the principal autumn fruit in Spain. It is related to the *Casaba*, but is of even better quality. Ripens from October to January. It is picked two weeks before being fully ripe and then kept in the dark. In shape it is oblong, rounded; skin rough with longitudinal green and warty ribs, between which the skin is colored bright green. Flesh transparent, yellowish amber to deep orange, solid, sweet, and highly flavored. A very superior variety, which can not be praised too highly."

32884. *ALLIUM CEPA* L.

Onion.

"Large white onion from Dilar."

32885. CYMBOPOGON sp.**Lemon grass.**

From Douglas Dale, Jeolikote Post Office, United Provinces, India. Presented by the Superintendent, Kumaon Government Gardens, Mr. Norman Gill. Received February 28, 1912.

Procured for the experiments with oil-producing grasses being carried on by the Office of Drug-Plant Investigations.

Plants.

32886. DIOSPYROS sp.**Persimmon.**

From Yokohama, Japan. Purchased from the Yokohama Nursery Co. Received February 28, 1912.

Cuttings.

32890 and 32891. GLYCINE HISPIDA (Moench) Maxim.**Soy bean.**

From Blacksburg, Va. Grown by the Virginia Agricultural Experiment Station. Received February 27, 1912.

Seeds of the following; quoted notes by Mr. W. J. Morse:

32890. "*Duggar*. Grown under No. 17268C at the Virginia Experiment Station, Blacksburg, Va., 1911. A field mass selection at Arlington Experimental Farm in 1907 out of S. P. I. No. 17268, *Ito San*. An olive-yellow seeded variety of medium maturity found especially promising in Alabama and Virginia."

32891. "*Austin*. The progeny of S. P. I. No. 17263 grown under No. 17263 at Virginia Experiment Station, Blacksburg, Va., 1911; originally from S. P. I. No. 6397 from Pingyang, Korea. This variety was also distributed under Agroetology No. 1539. A late olive-yellow seeded variety found especially promising in Virginia, Tennessee, and southern Pennsylvania."

32892. CAREX PHYSODES Bieb.

From Peshy Kara Kum Desert, Turkestan. Presented by Mr. W. W. Mackie, Esperanza, Sonora, Mexico, through Mr. D. A. Brodie, Acting Agriculturist in Charge, Office of Farm Management, Bureau of Plant Industry. Received February 29, 1912.

"This carex grows abundantly on the loose desert sand of the Peshy Kara Kum Desert of southern Turkestan. It produces excellent feed for horses, camels, sheep, donkeys, etc., with less than 4 inches of rain per annum. It grows only on the loose sand. The soil expert would class this sand as medium. To protect itself from the elements when the roots are exposed by the winds each root and rootlet gathers about itself a layer of sand several times its diameter, holding it against considerable strain and wear." (*Mackie*.)

32894 to 32900. PHOENIX DACTYLIFERA L.**Date.**

From the Siwa Oasis. Procured by Mr. George J. Salem, Cairo, Egypt. Received February 26, 1912.

Fruits of the following varieties; native names given by Mr. Salem; translations in parenthesis by Mr. Alexander Aaronsohn, Bureau of Plant Industry:

32894. *Frihy* (spirited).

32895. *Gazaly* (antelope). "This variety is not very productive, though its dates are marvelous in flavor, appearance, and power to keep long." (*Salem*.)

32894 to 32900—Continued.**32896.** *Gorm-Gazaly* (antelope's abode).**32897.** *Kaiby*.**32898.** *Saidy* (from Said, rural).**32899.** *Wedi* (valley or creek).**32900.** *Wish-Gobeil* (mountain slope).**32901. DIOSPYROS KAKI L. f.****Persimmon.**

From Algiers, Algeria. Presented by Dr. L. Trabut. Received March 2, 1912.

"*Boufarik*. A new variety. Fruit green, large, round, flattened, very good."
(Trabut.)

32902. NEPHELIUM LAPPACEUM L.**Rambutan.**

From Buitenzorg, Java. Presented by Mr. W. G. Gobius, Secretary to the
Department of Agriculture. Received March 1, 1912.

See No. 25165 for general description of this fruit.

32906 to 32909. GLYCINE HISPIDA (Moench) Maxim. Soy bean.

The following list represents some promising varieties of soy beans grown in
quantity at the Arlington Experimental Farm, Virginia, in 1911. Numbered
March 4, 1912, for convenience in recording distribution.

Seeds of the following; quoted notes by Mr. W. J. Morse:

32906. "*Virginia*. Grown under No. 19186D. A pure field selection at
Arlington farm in 1907 out of S. P. I. No. 19186, from Newchwang, Manchuria,
1906. A medium-late brown-seeded variety of considerable promise."

32907. "*Peking*. Grown under No. 17852B. A pure field selection at
Arlington Experimental Farm in 1907 out of S. P. I. No. 17852, *Meyer*, from
Peking, China. A medium-late variety with small black seeds. Very
prolific and especially promising as a hay variety."

32908. "*Chestnut*. Grown under No. 20405B. A field mass selection at
Arlington Experimental Farm in 1907 out of S. P. I. No. 20405, *Habaro*,
from Khabarovsk, Siberia, 1906. A medium-early brown-seeded variety of
promise in the more northern States."

32909. "*Auburn*. Grown under No. 21079A. A field mass selection at
Arlington Experimental Farm in 1907 out of S. P. I. No. 21079, *Shingto*,
from Tieling, Manchuria, 1907. A black-seeded variety in Pennsylvania
and New York."

32910. PHYTELEPHAS AEQUITRIONALIS Spruce. Ivory-nut palm.

From Guayaquil, Ecuador. Presented by Mr. Herman R. Dietrich, American
consul general. Received March 1, 1912.

Distribution.—An erect palm, sometimes 20 feet high, found on the plains in the
vicinity of Guayaquil and extending up the valleys in the Andes to an elevation of
5,000 feet, especially toward Mount Chimborazo, in Ecuador.

32911 to 32913.

From Lawang, Java. Presented by Mr. M. Buyaman. Received February
26, 1912.

32911 to 32913—Continued.

Seeds of the following:

32911. Aesculus turbinata Blume.

Distribution.—A tree found on wooded mountain slopes in the provinces of Kiangsu and Chekiang in China and in the islands of Japan.

32912. Pterocarya sorbifolia Sieb. and Zucc.

Distribution.—Wooded mountain slopes of Japan.

32913. Randia formosa (Jacq.) Schum.

Distribution.—The countries in the northern part of South America, including Guiana, Colombia, Venezuela, and Peru, and the islands of the Caribbean Sea.

32914 to 32916.

Presented by Mr. Walter Fischer, Campo de Cultura Experimental Paraense, Para, Brazil. Received February 27, 1912.

Seeds of the following; quoted notes by Mr. Fischer:

32914. Sapindus sp.

"A species of *Sapindus*, which I found along a roadside about 6 miles from Santarem. The tree grows to a height of 30 to 40 feet and is found along the borders of clearings. The natives were familiar with the saponifying property of the seeds, but as far as I could learn made no use of them. Santarem is located at the north of the Tapajos on the Amazon, about 500 miles from Para."

32915 and 32916. Pithecolobium unguis-cati (L.) Benth.

"Two varieties of seeds that I found and collected in Barbados. The local name is 'bread and cheese.' The seeds are from a very attractive ornamental small tree much used as a border shrub and as a hedge plant for which latter purpose it is well adapted. It has a clean foliage of compound leaves, each leaf consisting of a twin pair of obovate leaflets. What makes the plant most conspicuous and attractive is its heavy burden of dense panicles of pods, open and twisted when ripe and showing the shiny-black small seeds to each of which is attached a red or a white arillus. This hedge plant would be excellently adapted to southern Florida where it may already exist."

32915. "Seed with white aril."

32916. "Seed with red aril."

Distribution.—Sandy soil in southern Florida and in the West Indies and the tropical part of South America.

32917 to 32973.

From La Mortola, Ventimiglia, Italy. Presented by Prof. Alwin Berger, curator of the garden. Received March 2, 1912.

Seeds of the following:

32917. Ampelopsis humulifolia Bunge.

Distribution.—A vine found in the province of Chihli, Shingking, Kansu, and Hupeh in China, and in Chosen (Korea), Formosa, and in Japan.

32918. Argania spinosa (L.) Skeels.

Argan.

See Nos. 3490 and 28783 for previous introductions.

32919. Aristotelia macqui L'Heritier.

Maqui.

See No. 26306 for description.

32920. Berberis globosa Benth.

Barberry.

See No. 31245 for previous introduction.

32917 to 32973—Continued.

32921. *BERBERIS GUIMPFLI* Koch and Bouche. **Barberry.**
32922. *BERBERIS JAPONICA BRALEI* (Fortune) Skeels. **Barberry.**
See Nos. 31244 and 32700 for previous introductions.
32923. *BERBERIS NAPAULENSIS* (DC.) Spreng. **Barberry.**
See No. 28839 for description.
32924. *CAJUPUTI CUTICULARIS* (Labill.) Skeels.
(*Melaleuca cuticularis* Labill. 1806, *Novae Hollandiae Plantarum Specimen*, vol. 2, p. 30, pl. 171.)
32925. *CAJUPUTI ERICIFOLIA* (Smith) Lyons. **Bottle-brush tea-tree.**
See No. 30793 for previous introduction.
32926. *CAJUPUTI HYPERICIFOLIA* (Salisb.) Skeels. **Hillock tree.**
See No. 30761 for previous introduction.
32927. *CAJUPUTI PUBESCENS* (Schauer) Skeels.
See No. 30795 for previous introduction.
32928. *CAJUPUTI PULCHELLA* (R. Br.) Skeels.
(*Melaleuca pulchella* R. Br. 1812, *Aiton Hortus Kewensis*, ed. 2, vol. 4, p. 414.)
32929. *CAJUPUTI WILSONI* (Mueller) Skeels. **Wilson's tea-tree.**
(*Melaleuca wilsoni* Mueller 1861, *Fragmenta Phytographiae Australiae*, vol. 2, p. 124, pl. 15.)
- The reason for the use of the generic name *Cajuputi* in place of *Melaleuca* is explained in Inventory No. 27 (Bulletin 242, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1912, p. 39.) *Cajuputi cuticularis* is a tall shrub or small tree and *C. pulchella* is a low, spreading shrub, both growing along streams in West Australia. *C. wilsoni* is a tall shrub found in Victoria and South Australia.
32930. *CELTIS AUDIBERTIANA* Spach. **Hackberry.**
This species is generally referred to *C. occidentalis* L. As the latter is now considered to cover several distinct forms it is thought best to retain the present name until the material can be grown.
32931. *COLUTEA CILICICA* Boiss. and Bal.
Distribution.—A shrub found on the coast and on the slopes of the mountains in the southern part of Asia Minor from Smyrna to Cilicia.
32932. *COTONEASTER AFFINIS* Lindl.
See No. 28207 for previous introduction.
32933. *COTONEASTER BUXIFOLIA* Wall.
Distribution.—On the slopes of the Nilgiri Hills in the southern part of India.
32934. *COTONEASTER MICROPHYLLA* Wall.
Distribution.—A shrub found on the temperate slopes of the Himalayas at an altitude of 4,000 to 8,000 feet, between Kashmir and Bhutan in northern India.
32935. *COTONEASTER MICROPHYLLA THYMIFOLIA* (Loud.) Koehne.
Distribution.—A low shrub found on the alpine slopes of the Himalayas from Kashmir to Sikkim in northern India.
32936. *COTONEASTER PANNOSA* Franchet.
Distribution.—A low shrub found on limestone ledges of the mountains in the province of Yunnan in China at an elevation of 10,000 feet.

32917 to 32973—Continued.

32937. *COTONEASTER ROTUNDIFOLIA* Wall.

See No. 28211 for previous introduction.

32938. *COTONEASTER SIMONSI* Baker.

A half-hardy shrub. See No. 28212 for distribution of this species.

32939. *COTYLEDON BARBEYI* Schweinf.

Distribution.—An exquisite plant for carpet bedding found on the slopes of the mountains in the province of Yemen in western Arabia.

32940. *ELAEAGNUS LATIFOLIA* L.

Distribution.—From the subtropical and temperate slopes of the Himalayas southward to Ceylon in India, and throughout the Malay Archipelago.

32941. \times *ELAEAGNUS FUNGENS REFLEXA* (M. and D.) Rehd.

A spreading shrub, considered to be a hybrid between *Elaeagnus pungens* and *E. glabra*.

32942. *FRAXINUS ORNUS* L.

Ash.

Distribution.—A small tree found in southern Europe and western Asia, extending from Spain through southern France and Germany, Italy, and Greece to Asia Minor and Syria.

32943. *GERANIUM PALMATUM* Cav.

Distribution.—A herbaceous perennial found in the Canary Islands.

32944. *GREVILLEA THELEMANNIANA* Huegel.

Distribution.—A spreading shrub with racemes of pink flowers, found in the valley of the Swan River in West Australia.

32945. *ILEX CORNUTA* Lindl. and Paxton.

Chinese holly.

See No. 22979 for description of this species.

32946. *PODACHAENIUM EMINENS* (Lag.) Baill.

See No. 23850 for description of this species.

32947. *REHUS EXCISA FALLENS* (Eckl. and Zeyh.) Sond.

Distribution.—A shrub found in the Uitenhage and Albany districts of South Africa.

32948. *ROSA AGRESTIS* Savi.

Rose.

Distribution.—Western and southern Europe, extending from Sweden and Denmark southward through France to Italy, and in Morocco, Tunis, and Algiers.

32949. *ROSA CYMOSA* Trattinick.

Rose.

Distribution.—The provinces of Kiangsu, Chekiang, Kiangsi, Fokien, Hupeh, Kwangtung, and Hongkong in China.

32950. *ROSA DAMASCENA* Miller.

Rose.

32951. *ROSA DAMASCENA TRIGINTIPETALA* (Dieck) Koehne.

Distribution.—This is the form of *Rosa damascena* which is cultivated in Roumelia for the production of rose oil.

32952. *ROSA FENDLERI* Crepin.

Rose.

32953 to 32955. *ROSA INDICA* L.

Rose.

32953. Variety *borbonica*.

32954. Variety *major*.

32955. Variety *semperflorens fl. simpl.*

32917 to 32973—Continued.

32956. *ROSA LESCHENAULTIANA* (Red. and Thorry) Wight and Arn. Rose.

Distribution.—The slopes of the Nilgiri and Pulney hills in the western peninsula of India.

32957. *ROSA LYELLII* Lindl. Rose.

Distribution.—The province of Nepal in northern India; considered by some authorities to be a climbing form of *Rosa involucrata* Roxb.

32958. *ROSA OXYODON* Boiss. Rose.

Distribution.—The slopes of the eastern part of the Caucasus Mountains at an elevation of 6,000 feet.

32959. *ROSA PHOENICIA* Boiss. Rose.

Distribution.—Along the shores of the Mediterranean in Asia Minor and Syria.

32960. *ROSA SEMPERVIRENS* L. Rose.

Distribution.—Southern Europe, extending from Portugal and Spain eastward through southern France, Italy, and Greece to Asia Minor, and in northern Africa.

32961. *ROSA SERAPHINII* Viv. Rose.

Distribution.—The islands of Corsica, Sardinia, and Sicily, and in Italy.

32962. *ROSA SOULIEANA* Crep. Rose.

See No. 21747 for description.

32963. *ROSA SPINOSISSIMA* L. Rose.

Distribution.—Central Europe and Asia, extending from the British Isles and northern Spain eastward through Europe and Asia to Manchuria and northwestern China.

32964. *ROSA TOMENTELLA ALLIONII* (Burnat) Keller. Rose.

Distribution.—The slopes of the Maritime Alps between France and Italy.

32965. *ROSA VIRGINIANA* Miller. Rose.

See No. 28244 for previous introduction.

32966. *ROSA XANTHINA* Lindl. Rose.

See Nos. 28978 and 21620 for description.

32967. *ROSA* sp. Rose.

32968. *TECOMA PANDORANA* (Andrews) Skeels.

(*Bignonia pandorana* Andrews 1800, Botanists' Repository, vol. 2, pl. 86.)

The seeds of this Australian trumpet flower were received under the name *Tecoma australis*, which was published in 1810 by R. Brown (Prodromus, p. 471). Brown cited "*Bignonia pandorea* Andr." Andrews spelled the specific name "*pandorana*," and this name, being earlier, is here restored.

Distribution.—Found in North Australia, Queensland, New South Wales, and Victoria, in Australia.

32969. *PODRANEA RICASOLLANA* (Tanf.) Sprague.

Distribution.—A climbing shrub found in thickets at the mouths of streams in the eastern part of Cape Colony.

32970. \times *TRITOMA CORALLINA* Hort.

A hybrid between *Trioma macowani* (Baker) Skeels (*Kniphofia macowani* Baker, 1874, The Journal of Botany, vol. 12, p. 3), and *T. uvaria* (L.) Ker.

32917 to 32973—Continued.

32971. *TRITOMA NATALENSIS* (Baker) Skeels.(*Kniphofia natalensis* Baker, 1885, The Journal of Botany, vol. 23, p. 278.)32972. *TRITOMA NELSONI* (Masters) Skeels.(*Kniphofia nelsoni* Masters, 1892, Gardeners' Chronicle, ser. 3, vol. 11, p. 554, fig. 83.)

The necessity for using the generic name *Tritoma* for the plants usually referred to the genus *Kniphofia* is explained in Inventory No. 24 (Bulletin 223, U. S. Department of Agriculture, Bureau of Plant Industry, 1911, p. 25).

These species are all natives of South Africa, *Tritoma macowani* being found in the central and coast regions, *T. natalensis* in Natal and *T. nelsoni* in the Orange Free State.

32973. *TRITOMA TUCKER* (Baker) Skeels.

See No. 28526 for distribution of this species.

32975 to 33006.

From Tiflis, Caucasus, Russia. Presented by Mr. D. A. Roloff, Director, Botanic Garden. Received March 2, 1912.

Seeds of each of the following:

32975. *ACER TRAUTVETTERI* Medw.

Maple.

See No. 30531 for distribution of this species.

32976. *ASTRAGALUS BUNGEANUS* Boiss.

Distribution.—Stony mountain slopes in the Caucasus region of southeastern Russia.

32977. *ASTRAGALUS* sp.

This was received under the name *Astragalus cyri* Fomin, but as yet the place of publication of this name has not been found.

32978. *ASTRAGALUS KADSHORENSIS* Bunge.

Distribution.—Slopes of the mountains in the Tiflis region of southeastern Russia.

32979. *ASTRAGALUS MICROCEPHALUS* Willd.

Distribution.—On the slopes of the mountains in the northeastern part of Asia Minor and the southeastern part of Russia.

32980. *ASTRAGALUS URANIOLIMNEUS* Boiss.*Distribution*.—On the mountains in Armenia.32981. *CELTIS CAUCASICA* Willd.

See No. 30575 for previous introduction.

32982. *CORNUS AUSTRALIS* Meyer.

See No. 30570 for distribution of this species.

32983. *DAPHNE OLEOIDES* Schreber.

Distribution.—A shrub found on the subalpine mountain slopes in southern Europe, extending from Spain through Italy, Greece, and Turkey to Asia Minor and Syria, and in Algeria.

32984. *ELAEAGNUS ANGUSTIFOLIA* L.

Oleaster.

See No. 31822 for description.

32975 to 33006—Continued.

32985. *HEDERA COLCHICA* Koch.

Distribution.—The Trans-Caucasian region of southeastern Russia, and in northern Persia.

32986. *IRIS CAUCASICA* Hoffm.

Iris.

Distribution.—A pale or bright yellow-flowered iris, found in the Caucasus region of southeastern Russia and eastward through Asia Minor and Persia to Turkestan; ascending to an elevation of 6,000 feet.

32987. *IRIS RETICULATA* Bieb.

Iris.

Flowers bright purple, very fragrant.

Distribution.—Same as No. 32986.

32988. *JUNIPERUS EXCELSA* Willd.

Juniper.

See No. 26688 for description.

32989. *JUNIPERUS FORTIDISSIMA* Willd.

Juniper.

See No. 29246 for description.

32990. *JUNIPERUS OXYCEDRUS* L.

Juniper.

See No. 26884 for description.

32991. *LALLEMANTIA IBERICA* (Bieb.) Fisch. and Meyer.

See No. 29932 for description.

32992. *LATHYRUS ROSEUS* Steven.

A hardy herbaceous climber with beautiful rose-colored flowers.

Distribution.—Wooded mountain slopes in the Trans-Caucasian region of Russia and in Asia Minor.

32993. *LATHYRUS ROTUNDIFOLIUS* Willd.

Persian everlasting pea.

"A low-growing winged species with large, rose-pink flowers is of easy culture requiring a cool, shady, and sheltered position. Adapted to stony banks." (*Bailey's Cyclopedia of American Horticulture*, p. 888.)

Distribution.—Southeastern Russia, Asia Minor, and the northern part of Persia.

32994. *LAUROCERASUS OFFICINALIS* Roem.

Laurel cherry.

See Nos. 27360 and 27684 for description.

32995. *LONICERA BRACTEOLARIS* Boiss. and Buhse.

Honeysuckle.

Distribution.—A shrub found in the vicinity of Tassakend in the province of Karabagh in the Caucasus region of Russia.

32996. *PAEONIA MLOKOSIEWITSCHI* Lomakin.

Peony.

See No. 27674 for description.

32997. *PAEONIA WITTMANNIANA* Hartwiss.

Peony.

Distribution.—Subalpine slopes of the mountains in the northern part of Persia.

32998. *PALIURUS SPINA-CHRISTI* Miller.

Christ's-thorn.

See No. 26879 for description.

32999. *PISTACIA MUTICA* Fisch. and Meyer.

See No. 9474 for description.

Distribution.—On the lower slopes of the mountains in Asia Minor, Persia, and western Afghanistan.

32975 to 33006—Continued.**33000. POPULUS TREMULA L.****Poplar.**

See No. 29098 for description.

33001. PYRUS NIVALIS ELAEAGRIFOLIA (Pall.) Schneider.**Wild pear.**

See No. 27670 for description.

33002. RHAMNUS PALLASII Fischer.

See No. 27669 for description.

33003. SOLANUM NIGRUM L.**Nightshade.****33004. SOLANUM NIGRUM L.****Nightshade.**Variety *chlorocarpum*.**33005. TRIFOLIUM ANGUSTIFOLIUM L.****Clover.**

See Nos. 7753 and 9750 for previous introductions.

Distribution.—The countries bordering on the Mediterranean from Spain to Syria, and in northern Africa.**33006. VICIA PERSICA Boiss.***Distribution.*—Alpine regions of Armenia and northwestern Persia.**33007. HIBISCUS MUTABILIS L.**

From Kiaying chow, China. Presented by Mr. George Campbell. Received March 5, 1912.

"This is a showy plant with blossoms something like a hollyhock; with me it grew to be about 3 feet high by blossoming time, and had a profusion of great double flowers with five centers; hence called *ng-im-to*, or five-heart-blossom, *Fu-yung*. More than half of them blasted and dropped off, but those left fairly weighed down the little tree. It blossomed November 2. This double kind is rather rare, but is propagated by cuttings." (*Campbell*.)

Distribution.—Common in China, except in the colder parts, both wild and cultivated; also cultivated in most warm countries.

33008 to 33068.

From Kew, England. Presented by Dr. David Prain, Director, Royal Botanic Garden. Received February 3, 1912.

Seeds of the following:

33008 to 33013. Herbaceous plants.**33008. CHRYSANTHEMUM CINERARIAEFOLIUM (Trev.) Vis.****Pyrethrum.****33009. HYPERICUM FRAGILE Heldr. and Sart.**

Distribution.—A very low-growing *Hypericum* found in the fissures of the rocky slopes of the Delphi Mountains in the vicinity of Steni, in eastern Greece.

33010. MECONOPSIS ACULEATA Royle.

Distribution.—A herbaceous perennial with blue-purple flowers found on the Himalayas from Kashmir to Kumaon, in northwestern India.

33011. MECONOPSIS CAMBRICA Viguiet.**Welsh-poppy.**

Distribution.—A herbaceous perennial with pale-yellow flowers found in rocky places in the woods in western Europe from the British Isles southward to Spain.

33008 to 33068—Continued.

33008 to 33013—Continued.

33012. *MECONOPSIS HETEROPHYLLA* Benth.

Distribution.—From the San Francisco Bay region southward to southern California.

33013. *MECONOPSIS RACEMOSA* Maxim.

Distribution.—A herbaceous perennial found in the province of Kansu, in the northwestern part of China.

33014 to 33068. Trees and shrubs.

33014. *ACER NIKOENSE* (Miq.) Maxim.

Maple.

A very distinct species; leaves turn brilliant scarlet in autumn.

Distribution.—The wooded subalpine slopes of the mountains in the islands of Tozando and Kiushu, in Japan.

33015. *BERBERIS ACUMINATA* Franch.

Barberry.

See Nos. 22545 and 29957 for previous introductions.

33016. *BERBERIS ANGULOSA* Wall.

Barberry.

See No. 27115 for previous introduction.

33017. *BERBERIS ARISTATA* DC.

Barberry.

See Nos. 27116 and 32789 for previous introductions.

33018. *BERBERIS CONCINNA* Hook. f.

Barberry.

See No. 27117 for previous introduction.

33019. *BERBERIS DICTYOPHYLLA* Franch.

Barberry.

See Nos. 27118, 27400, and 27401 for previous introductions.

33020. *BERBERIS HOOKERII* Lemaire.

Barberry.

Distribution.—Supposed to be a native of the slopes of the eastern Himalayas, in northern India.

33021. *BERBERIS ORTHOBOTRYS* Bienert.

Barberry.

Distribution.—In the province of Kashmir and in northern India, in Afghanistan, and in northeastern Persia.

33022. *BERBERIS PARVIFOLIA* Sprague.

Barberry.

See No. 29958 for previous introduction.

33023. *BERBERIS UMBELLATA* Wall.

Barberry.

See No. 27121 for previous introduction.

33024. *BERBERIS* sp.

Barberry.

This was received under the name *Berberis vilmoriniana*, but as yet the place of publication of this name has not been found.

33025. *BERBERIS YUNNANENSIS* Franch.

Barberry.

Distribution.—On the slopes of the mountains at an altitude of 10,000 feet in the Province of Yunnan, in southwestern China.

33026. *CLEMATIS MONTANA* Hamilton.

Clematis.

Variety *rubens*.

33027. *COLUTEA ARBORESCENS* L.

See Nos. 1570 and 30786 for previous introductions.

33028. *COLUTEA* sp.

This was received under the name *Colutea bullata*, but as yet the place of publication of this name has not been found.

33008 to 33068—Continued.**33014 to 33068—Continued.****33029. COLUTEA ISTRIA** Miller.

Distribution.—A tall shrub found in the mountains of Syria and southward through Arabia to Abyssinia.

33030. X COLUTEA MEDIA Willd.

Considered to be a hybrid between *Colutea arborescens* L. and *C. orientalis* Miller.

33031. COTONEASTER AFFINIS Lindl.

See Nos. 28207 and 32932 for previous introductions.

33032. COTONEASTER AFFINIS BACILLARIS (Wall.) Schneider.

See No. 28208 for previous introduction.

33033. COTONEASTER APPLANATA Arranger.

See No. 29963 for previous introduction.

33034. COTONEASTER BULLATA Bois.

See No. 29964 for previous introduction.

33035. COTONEASTER BUXIFOLIA Wall.

See S. P. I. No. 32933 for distribution.

Distribution.—On the slopes of the Nilgiri Hills in the southern part of India.

33036. COTONEASTER FRANCHETI Bois.

Distribution.—On the mountain slopes in Tibet and in the province of Yunnan in southwestern China.

33037. COTONEASTER FRIGIDA Wall.

Distribution.—A tall shrub or small tree found on the slopes of the Himalayas at an altitude of 7,000 to 10,000 feet in the provinces of Nepal and Sikkim in northern India.

33038. COTONEASTER HORIZONTALIS Decaisne.

See Nos. 1595 and 28209 for previous introductions.

33039. COTONEASTER INTEGERRIMA Medic.

See Nos. 22695 and 29966 for previous introductions.

33040. COTONEASTER LINDLEYI Steud.

Distribution.—On the slopes of the Himalayas in Kashmir, India, and in Afghanistan.

33041. COTONEASTER MICROPHYLLA GLACIALIS Hook.**33042. COTONEASTER MICROPHYLLA THYMIFOLIA** (Loud.) Koehne.

See No. 32935 for previous introduction.

Distribution.—A low shrub found on the alpine slopes of the Himalayas from Kashmir to Sikkim in northern India.

33043. COTONEASTER PANNOSA Franchet.

See No. 32936 for previous introduction.

33044. COTONEASTER RACEMIFLORA NUMMULARIA (Fisch. and Mey.) Dipp.**33045. COTONEASTER ROTUNDIFOLIA** Wall.

See Nos. 28211 and 32937 for previous introductions.

33008 to 33068—Continued.

33014 to 33068—Continued.

33046. *COTONEASTER SIMONSI* Baker.

See Nos. 28212 and 32938 for previous introductions.

33047. *COTONEASTER* sp.

(Forrest, 5545, China.)

33048. *ELAEAGNUS MULTIFLORA* Thunb.

Oleaster.

See No. 2670 for description.

Distribution.—Throughout Japan, where several varieties are cultivated for their fruit, and in the provinces of Kiangsi and Hupeh in China.33049. *ENKIANTHUS CAMPANULATUS* (Miq.) Nichols.*Distribution*.—On the subalpine slopes of the mountains in the islands of Hondu and Hokushu in Japan.33050. *EXOCHORDA ALBERTI* Regel.

A shrub found in Bokhara in central Asia.

See No. 1767 for previous introduction.

33051. *LIGUSTRUM* sp.

Privet.

(Forrest, 5984, China.)

33052. *LONICERA HENRYI* Hemsl.

Honeysuckle.

Distribution.—A climbing shrub found in the Patung district of the province of Hupeh in China.33053. *LONICERA MAACKII* (Rupr.) Herd.

Honeysuckle.

See No. 22548 for previous introduction.

Distribution.—The provinces of Shingking, Kiangsi, Kiangsu, and Hupeh in China, and in Manchuria and northern Japan.33054. *LONICERA PERICLYMENUM* L.

Honeysuckle.

Variety *belgica*.33055. *LONICERA XYLOSTEUM* L.

Honeysuckle.

Distribution.—Throughout Europe and northern Asia, extending southward to the Caucasus and the valley of the Amur.33056. *MALUS MEDWIETZKYANA* Dieck.

See Nos. 27123 and 30250 for previous introductions.

33057. *MALUS SIKKIMENSIS* (Hook. f.) Koehne.

See No. 27127 for previous introduction.

33058. *RHAMNUS* sp.33059. *RHAMNUS FRANGULA* L.

Alder buckthorn.

See Nos. 2179, 30248, and 30573 for previous introductions.

33060. *RHODODENDRON CAUCASICUM* Pallas.*Distribution*.—Alpine summits of the Caucasus Mountains in south-eastern Russia.33061. *SOPHORA DAVIDI* (Franchet) Skeels.*(Sophora viciifolia* Hance 1881, Journal of Botany, vol. 19, p. 209; not *S. viciaefolia* Salisbury 1796, Prodrum, p. 328.)*(Sophora moorcroftiana davidi* Franchet 1883, Nouvelles Archives du Museum D'Histoire Naturelle, Paris, ser. 2, vol. 5, p. 253, pl. 14.

33008 to 33068—Continued.**33014 to 33068—Continued.**

The seeds of this spreading leguminous Chinese shrub were received under the name *Sophora viciifolia*, which was published by Hance in 1881. However, in 1796 Salisbury had published the name *Sophora viciaefolia* for the plant now generally known as *Virgilia capensis*. As it is not allowable to use the same specific name more than once in the same genus, *Sophora viciifolia* Hance is rejected as a homonym. The next name applied to this species was *Sophora moorcroftiana davidi* Franchet; and as it is considered to be distinct from the Indian plant, *S. moorcroftiana*, it is here raised to specific rank.

Sophora davidi was found by Hance in the vicinity of Ichang, in the province of Hupeh, and is also known to grow in the province of Shensi, in China.

33062. VIBURNUM COTINIFOLIUM D. Don.

Distribution.—A spreading shrub, often 10 feet high, growing at an altitude of 6,000 to 11,000 feet on the slopes of the Himalayas between Kashmir and Kumaon in the northern part of India.

33063. VIBURNUM PHLEBOTRICHUM Sieb. and Zucc.

Distribution.—Wooded mountain slopes in the islands of Hondu and Kiushu in Japan.

33064. VIBURNUM PUBESCENS Pursh.**33065. VIBURNUM RHYTIDOPHYLLUM Hemsl.**

Distribution.—A shrub with large, coarsely wrinkled leaves found in the Patung district of the province of Hupeh, China.

33066. VIBURNUM SARGENTI Koehne.

See No. 30847 for previous introduction.

33067. VIBURNUM WRIGHTII Miq.

Distribution.—On the hillsides and mountain slopes of the Hakodate peninsula in the island of Hokushu in Japan.

33068. × PHYSALIS BUNYARDI Hort.

"This is a cross between *Physalis francheti* and *P. alkekengi*. The colored calyces are much less in size than those of *P. francheti*, and in general appearance the hybrid is about intermediate between the parents. When the growths are cut and the calyces fully colored, the leaves are still in a fresh condition, and for this reason as well as for the less stiff character of the shoots as compared with *P. francheti*, the hybrid may be more valued for use in decorative purposes." (*Gardeners' Chronicle*, vol. 38, 1905, p. 315, fig. 123.)

33069 and 33070. DIOSPYROS KAKI L. f.

Persimmon.

From Wakamatsu, Japan. Presented by Rev. H. Loomis, American Bible Society, Yokohama. Received March 7, 1912.

Cuttings of the following:

33069. Hassaku.

33070. Mishirodu. "I have grown this variety in my garden for several years and regard it as one of the very best. It is a prolific bearer (the name signifies that the tree takes no thought of itself), it is rich in flavor, very sweet, and not astringent. In size and appearance it resembles *Gema*." (Loomis.)

33071. FIGUS MACROPHYLLA Desf.**Moreton Bay fig.**

From Sydney, New South Wales, Australia. Presented by Prof. J. H. Maiden, Director and Government Botanist, Royal Botanic Garden. Received March 7, 1912.

"This only grows in the well-watered coastal district, and experiments with the view to introduce it into drier localities have almost invariably resulted in failure." (Maiden.)

See No. 3494 for previous introduction.

Distribution.—A large tree found near streams in Queensland and New South Wales in Australia.

33073. HEDYSARUM CORONARIUM L.**Sulla.**

From Jerez de la Frontera, Spain. Presented by Mr. Percival Gassett, American consul. Received March 7 and 19, 1912.

"The sulla plant, or Spanish wild clover, is found in Spain only in southern Andalusia, province of Cadiz, where it grows wild and with most luxuriance in abandoned vineyards. The Spaniards are well aware of the great value of this plant as a rich forage for stock, especially for horses, to whom it is said to give endurance; and not enough sulla can be produced in Jerez to supply the demand, for, after the stock raisers and farmers who grow it have supplied themselves, any surplus is eagerly purchased by the military officers in charge of the Jerez Deposito Semental or depot for breeding horses for the Spanish army. So far, all efforts to make it grow in other parts of Spain, even at Seville, 90 miles from Jerez, have been unsuccessful.

"Practically, then, sulla needs the same climate and soil that produce the famous Jerez, or sherry, grape, unique of its kind in the world. The climate should be sunny, hot, and dry in the summer, with plenty of rain in the fall, and a low temperature that does not reach freezing, although occasional frosts during the winter nights are not unknown in Jerez. When there has been plenty of rain in the fall there has usually been an abundant crop of sulla the next spring.

"Now as to soil. Jerez has three soils, each of which produces a distinct type of wine; the best is known as 'albariza' (lime), the second best as 'barro' (clay), and the least desirable as 'arena' (sand). As a general rule the soil of Jerez vineyards is of a porous character, light, and of a grayish color, the composition of which, according to an analysis made in 1898 in the laboratory of the London Lancet is as follows:

	Per cent.
Calcium carbonate	29.12
Oxide of iron	4.08
Sand, etc	45.80
Soluble salts . . . . .	.50
Moisture	16.70
Loss on ignition	3.80
	<hr/>
	100.00

"Practically a third part of this soil consists of carbonate of lime and if the fact of producing the nearest imitation of Jerez wine is any indication, it would seem as if sulla might grow in parts of California.

"Although the general belief, which seems to be supported by all other unsuccessful experiments, is that this soil is indispensable for the successful growth of sulla, yet the writer has within a month or so seen an entire field of sulla, a foot or more in height, growing in ordinary black soil, without irrigation, at the Jerez Agricultural Experiment Station, La Granja.

"In planting, the unhusked seed was immersed for 5 minutes in boiling water, or the husked seed in water at 140° F. The seed was sown not later than the next day after this treatment. A good plan is to sow the sulla with wheat or barley and after the latter has been harvested it will come up the following autumn. It is said that if the sulla fails to grow one year and is not disturbed it will come up the year after; under favorable conditions it should grow as high as 3 or 4 feet." (*Extract from report of Mr. Gassett.*)

Distribution.—The countries bordering on the Mediterranean from Spain to Asia Minor and in northern Africa.

33074 to 33076. VITIS VINIFERA L.

Grape.

From Bhamdun, located on the western slope of Mount Lebanon, Syria. Presented by Mr. Alfred Ely Day, Syrian Protestant College, Beirut, Syria. Received February 26, 1912.

Cuttings of the following; quoted notes by Mr. Day:

33074. "*Katifi-dakar*. White berry, size and shape of an olive. Loose cluster. Ripens late and may be kept for winter eating."

33075. "*Aswad-kari*. Berries oval, of moderate size, black streaked with red, tough skin, firm pulp, ripening late, but not so late as *Shatawi* (S. P. I. No. 33113.)"

33076. "*Khudud-ul-banat* (maiden's cheeks). Much like *Mitsdi* (S. P. I. No. 33115), but red in color."

33077 to 33079.

From Siberia. Collected by Mr. Frank N. Meyer, agricultural explorer, Bureau of Plant Industry. Received January 6, 1912. Numbered March 10, 1912.

Seeds of the following; quoted notes by Mr. Meyer:

33077. *LARIX SIBIRICA* Ledeb.

Siberian larch.

From Marka Kul, Altai Mountains, southern Siberia. Altitude 6,000 feet.

"(June 8, 1911.) Large cones."

See No. 2175 for previous introductions.

33078. *PICEA OBOVATA* Ledeb.

Spruce.

From Marka Kul, Altai Mountains, southern Siberia. Altitude 5,000 to 7,000 feet.

"(June 7, 8, 9, 1911.) Cones from different localities around Lake Marka Kul."

See No. 20319 for previous introduction.

33079. *PINUS CEMERA* L.

Pine.

From Omsk, Siberia.

"(August 5, 1911.) Cones brought in from the Ural Mountains."

See Nos. 20317, 20764, and 20777 for previous introductions.

33080. GOSSYPIUM BARBADENSE L.

Cotton.

From Cairo, Egypt. Presented by Mr. George J. Salem. Received March 8, 1912.

"*Sekallaridis*. This variety has become somewhat popular in the provinces of lower Egypt, and has been grown during the last two years extensively in those provinces. It resembles much the *Jannowitch*, though its fiber is finer and its color more yellowish." (*Salem.*)

33081 to 33085. MECONOPSIS spp.

From Glasnevin, Dublin, Ireland. Presented by Mr. F. W. Moore, keeper, Royal Botanic Gardens. Received March 9, 1912.

Seeds of the following:

33081. MECONOPSIS CAMBRICA Viguier.

See No. 33011 for previous introduction.

33082. MECONOPSIS CAMBRICA Viguier.

Flore pleno.

33083. MECONOPSIS INTEGRIFOLIA (Maxim.) Franch.

See Nos. 13340 and 31269 for previous introduction.

33084. MECONOPSIS PANICULATA (Don) Prain.

Distribution.—A herbaceous perennial with yellow flowers, found on the slopes of the Himalayas in the provinces of Nepal, Sikkim, and Bhutan in northern India.

33085. MECONOPSIS WALLICHII Hooker.

See No. 25070 for previous introduction.

33086 to 33088. DIOSPYROS KAKI L. f. Persimmon.

From Okitsu, Japan. Presented by Mr. T. Tanikawa, in charge, Government Horticultural Experiment Station. Received March 9, 1912.

Cuttings of the following; quoted notes by Mr. Tanikawa:

33086. "Zenjimarū." A sweet variety, with male, female, and complete flowers in the same stock."

33087. "Fuji." One of the best astringent varieties in our country."

33088. "Fuyu." One of the best sweet varieties in this country."

33089 and 33090. GOSSYPIUM spp. Cotton.

From Abyssinia. Presented by Mr. Guy R. Love, American vice consul general, Addis Abeba. Received March 9, 1912.

Seeds of the following; quoted notes by Mr. Love:

33089. "Gojamie." From Gojam, south of Lake Tsana."

33090. "Gondarie." From Gondar, north of Lake Tsana."

"The cotton raised in the Lake Tsana district is of a much superior quality, being of longer fiber and lighter in color."

33091. MEDICAGO SATIVA L. Alfalfa.

From Bordj bou Arreridj, Algeria. Presented by Mr. F. Couston, agricultural engineer. Received November 8, 1911. Numbered March 11, 1912.

"(Blue flowers.) Spontaneous on the high plateaus at Bordj bou Arreridj; calcareous soils, sometimes very dry." (Couston.)

33092. CUCUMIS SATIVUS L. Cucumber.

From Yaroslav Province, Russia. Presented by Mr. Joseph A. Rosen, Chief, American Agricultural Bureau of the Governmental Zemstvo of Yekaterinoslav, Russia, at Minneapolis, Minn. Received March 8, 1912.

"Variety *Muromsky*. Originated in the province of Yaroslav, Russia. The earliest variety grown in Russia. Prolific, excellent quality. An open-ground variety, but is frequently grown also under glass." (Rosen.)

33093. DAMMARA ALBA Rumph.

From Buitenzorg, Java. Presented by Mr. H. Wigman, Botanic Garden. Received March 9, 1912.

"This beautiful broad-leaved conifer, related to the noted kauri pine of New Zealand, is worthy of trial in Florida and southern California. Its pyramidal, ever-green character makes it particularly suitable for avenue planting." (*David Fairchild*.)

Distribution.—A tall tree belonging to the pine family, found in the islands of the Malay Archipelago.

33094. BELOU MARMELOS (L.) Lyons.**Bael.**

From Peradeniya, Ceylon. Presented by Mr. H. F. Macmillan, Curator, Royal Botanic Garden. Received March 9, 1912.

See No. 24450 for description.

33096. CHIOCOCOA ALBA (L.) Hitchc.

From Palm Beach, Fla. Presented by Mr. J. B. Donnelly, manager, Clarke Estate. Received March 4, 1912.

"This plant when growing in the jungle climbs on trees, but when in the open and cut back a couple of times it makes a nice shrub that is covered with white berries which remain on all winter." (*Donnelly*.)

Distribution.—From the West Indies and Mexico, southward to Brazil and Peru.

33097. FICUS CARICA L.**Caprifig.**

From Chenoua, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received March 12, 1912.

"Very early." (*Trabut*.)

33098. PHASEOLUS CALCARATUS Roxb.

From Cuba. Presented by Mr. Robert L. Luáces, Camaguey, who secured them from Mr. Luis de Megret, editor, *El Agricultor Práctico*, Guantánamo, Oriente, Cuba. Received March 12, 1912.

"Little Devil, or Mambi, bean. An indigenous legume, found growing wild in the woods of Oriente Province, especially in the valley of Guantánamo. A climbing vine of vigorous growth that covers and smothers the tree over which it grows; for this reason the native country people call it 'Little Devil.' It is also called 'Mambi'¹ because it was discovered as an edible by the Cuban soldiers during the war of 1868-1878.

"It produces its fruits in clusters formed of eight or more small pods, each containing from six to eight beans. It starts to grow in early springtime and matures its fruit in autumn, the plant dying after fruiting. The pods must be gathered ripe. When allowed to dry on the vine they will burst, throwing the seed afar with much violence. The beans are very heavy, considering their small size, and are delicious in taste, selling in the local market at from 8 to 10 cents per pound." (*Megret*.)

33099. STRYCHNOS sp.

From Sombrero Negro, Nicaragua, near Rama. Collected by Mr. Carlos Berger, January, 1912. Received through Mr. W. E. Safford, Bureau of Plant Industry, March 12, 1912.

"Local name, *Madronito*. Roots used as a remedy for snake bites. Pulp of fruit edible." (*Safford*.)

¹"'Mambi', name given the Cuban soldier during the war of 1868-1878, from man (English) and bi (Latin)." (*Luáces*.)

33100. ADANSONIA DIGITATA L.**Baobab.**

From Cuba. Presented by Mr. Robert L. Luáces, Camaguey, who secured them from Mr. Luis de Megret, editor, *El Agricultor Práctico*, Guantánamo, Oriente, Cuba. Received March 13, 1912.

"The tree that produces this fruit is native to Africa and was introduced into Oriente Province by the French immigrants from Haiti. The tree, from its gigantic corpulence, leaf, and branch formation, looks very much like the Ceiba. The fruit is long, gourd shaped, of very hard skin, containing, enveloped in a white pasty or starchy stuff, a large number of small seeds. This starchy substance when water is applied to it is somewhat like arrowroot, its taste is subacid, and makes a good refreshing soft drink with sugar and water.

"It receives its name, 'monkey-bread', from the similarity of its seeds to the face of a monkey.

"It can be propagated from seed or from cuttings. This last method is the best, giving quickest results, for it takes some 10 years to grow it from seed. The fruit is hard and will keep for a long time." (*Megret.*)

Seeds.

33101. (Undetermined.)

From Kiayingchow, China. Presented by Mr. George Campbell. Received February 21, 1912.

"This is a rather handsome tree, 25 or 30 feet high; the curious fruits have a pleasant nutty flavor and are ripe about the last of November.

"I saw in a wayside inn up near the Fukien border three great planks of the wood of this *Pit-kiu* or *Kit-kiu* tree. They were 16 to 18 feet long and 18 inches wide and about 3 inches thick. The owner told me he got five such planks out of one tree and sold two of them for \$10 apiece. They are in demand for store counters, as they take a good polish and are very hard and dense in texture. But the fruit is the most interesting part of the tree. The fruit looks like the meat of hickory nuts, all crinkly, and is similar in taste. It is thin skinned and the texture is also somewhat like the hickory nut. The whole fruit is eaten, and there is a sort of string that comes from the fruit which you strip off as you eat. The seeds are little and black in color and are by themselves on the end of the fruit. They resemble a bedbug in appearance. This fruit is not of commercial value. The fruit is sold in China, however." (*Campbell.*)

33102 and 33103.

From Nice, Alpes-Maritimes, France. Presented by Dr. A. Robertson Proschowsky, Jardin d'Acclimatation Les Tropiques, Chemin des Grottes Sainte-Helene. Received March 11, 1912.

Seeds of the following; quoted notes by Dr. Proschowsky:

33102. BOCCONIA FRUTESCENS L.

"These seeds are so oily that if they were produced in large enough quantity perhaps some use could be made of them. The plant is very beautiful and forms a large evergreen shrub of striking foliage."

Distribution.—Tropical America, extending northward to the valley of the Cordova in Mexico; also in the West Indies.

33103. GREWIA sp.

"There is only a very little flesh on these fruits, but it is sweet and agreeable. As a beautiful flowering and very drought-resistant shrub it already has some value.

33104. FICUS RUBIGINOSA Desf.**Port Jackson fig.**

From Sydney, New South Wales, Australia. Presented by Prof. J. H. Maiden, Director and Government Botanist, Royal Botanic Garden. Received July 3, 1911. Numbered March 15, 1912.

"This grows in the coast districts, but extends a little more westerly than does *Ficus macrophylla* (S. P. I. No. 33071) and has shown greater adaptability to drier localities than that species." (Maiden.)

Seeds.

Distribution.—A tree found in the valleys of streams in New South Wales, Australia.

33105. MEIBOMIA HETEROCARPA (L.) Kuntze.

From Peradeniya, Ceylon. Presented by Mr. H. F. Macmillan, curator, Royal Botanic Garden. Received March 9, 1912.

33106 to 33110. COLOCASIA sp.**Taro.**

From Hilo, Hawaii. Presented by Mr. F. A. Clowes, Superintendent, Hawaii Sub-stations. Received March 13 and 14, 1912.

Tubers of the following varieties:

33106. *Manapiko*.

33109. *Kuoho*.

33107. *Wehiwa*.

33110. *Lehua*.

33108. *Elepaio*.

33111 to 33118. VITIS VINIFERA L.**Grape.**

From Bhamdun, located on the western slope of Mount Lebanon, Syria. Presented by Mr. Alfred Ely Day, Syrian Protestant College, Beirut, Syria. Received March 15 and 16, 1912.

Cuttings of the following; quoted notes by Mr. Day:

33111. "*Jauzani*. Large, white, thin-skinned berry, produced in crowded clusters. Sometimes the berries are partly large and partly small, in which case they are called 'hen and chickens.' The leaves are used in cooking, wrapped around small rolls of rice and chopped meat. This is one of the best grapes."

33112. "*Shahmâni*. Large, round, yellowish berry; firm pulp."

33113. "*Shatawi*. Not very sweet, a little larger, has a thicker skin, and ripens later than *Kârâfi-dakar* (S. P. I. No. 33074). *Shatawi* means belonging to winter."

33114. "*Âsmi*. This vine has short branches; clusters large; berries round and greenish, skin very thin. Much esteemed."

33115. "*Mikâsi*. The most useful grape of Lebanon for eating, wine, raisins, and sirup. Berries are of moderate size, white, with thin skin and soft pulp. Ripens early."

33116. "*Jbâ'i*. Berry black with hard skin, very firm and solid, not very juicy, good for preserving."

33117. "*Zeini*. Long white berries, moderate in size, sweet with a little acidity."

33118. "*Kârâfi-inti*.¹ Like *Kârâfi-dakar*¹ (S. P. I. No. 33074), but sweeter, thinner skinned, larger berries and clusters. Ripens after *Mikâsi* (S. P. I. No. 33115), but before *Shatawi* (S. P. I. No. 33113). Called *Kârâfi* because the berries with their stalklets easily break off from the clusters."

¹"'Inti' means female, and 'dakar,' male."

33119. AESCHYNOMENE ELAPHROXYLON (Guill. and Perr.) Taubert.
Ambach.

From Lawang, Java. Presented by Mr. M. Buysman, Botanic Garden. Received March 16, 1912.

"This is a Senegambian plant, much cultivated in several parts of Africa and also in Egypt. The only use is that of the wood, which is light and perhaps might be taken as a surrogate for cork. The stem gets very thick with age, but the height is moderate." (*Buysman.*)

Distribution.—A leguminous, spiny shrub up to 20 feet high, with large orange-colored flowers, growing in or near water on the west coast of Africa in Upper Guinea and Lower Guinea, and from the valley of the White Nile to the Mozambique district on the east coast.

33120. FRAXINUS ORNUS L. **Ash.**

From Germantown, Philadelphia, Pa. Purchased from Mr. Conyers B. Fleu, jr. Received March 18, 1912.

This seed was procured for experimental purposes in the semiarid regions of the United States.

33121 to 33126. ZEA MAYS L. **Corn.**

From Ecuador. Presented by Mr. Edward Harold Pound, Washington, D. C. Received March 18, 1912.

Seeds of the following:

33121 to 33124. From Chillo-Ordofiez, Quito, Ecuador.

33125 and 33126. From Hidalgo hacienda, Tumbaco, near Quito, Ecuador.

33127 to 33132. CARICA PAPAYA L. **Papaya.**

From Buitenzorg, Java. Presented by the Director, Botanic Gardens. Received March 18, 1912.

"Seed of different varieties of papayas, producing fruits of various shape and outline. The quality is good and there is but little difference between them." (*The Director.*)

33135. SALIX FRAGILIS L.

(♂ var. *pendula*.)

From Algeria. Presented by Dr. L. Trabut, Algiers. Received March 19, 1912.

"An Algerian ornamental." (*Trabut.*)

33136. GOSSYPIUM OBTUSIFOLIUM Roxb. **Cotton.**

From Algeria. Presented by Dr. L. Trabut, Algiers. Received March 19, 1912.

"Variety *africanum*. Perennial cultivated in the oasis. The very mediocre cotton is used by the natives to mix with wool. Oasis Insalah, The Djerid." (*Trabut.*)

33137. CHAETOCHLOA COSTATA (Roxb.) Skeels.

From Sibpur, near Calcutta, India. Presented by Maj. A. T. Gage, Superintendent, Royal Botanic Garden. Received March 19, 1912.

See No. 32399 for previous introduction.

33138 to 33179.

From Paris, France. Presented by the Director, Museum of Natural History.
Received March 19, 1912.

Seeds of the following:

33138. \times ACER BOSCH Spach. Maple.

Considered to be a hybrid between *Acer tataricum* L. and *A. pennsylvanicum* L.

33139. ALNUS MARITIMA (Marsh.) Muhl. Alder.

An ornamental shrub or small tree with handsome, shining foliage, attractive in autumn with its male catkins.

Distribution.—The eastern coast of North America, and in Japan, Chosen (Korea), and Manchuria.

33140. AMPELOPSIS HUMULIFOLIA Bunge.

See No. 32917 for previous introduction.

33141. AMPELOPSIS ORIENTALIS (Lam.) Planchon.

Distribution.—Shady banks in Cilicia, Syria, and Armenia.

33142. ARALIA CACHEMIRICA Decaisne.

See No. 30285 for previous introduction.

33143. ASPARAGUS OFFICINALIS L. Asparagus.

Distribution.—The countries at the western end of the Mediterranean from Spain and Italy and the adjacent islands to northern Africa and the Canary Islands.

33144. ASPARAGUS MARITIMUS Miller. Asparagus.

Distribution.—Southern Europe, extending from Spain eastward through Italy and Greece to the Caucasus region, and in southwestern Siberia.

33145. ASPARAGUS OFFICINALIS CASPIUS (Schult.) Asch. and Graebn.

Asparagus.

Distribution.—In the parts of southeastern Russia and northern Persia bordering on the Caspian Sea, and occasionally in the countries along the northern coast of the Mediterranean.

33146. ASPARAGUS OFFICINALIS PROSTRATUS (Dum.) Baker. Asparagus.

Distribution.—Considered to be a seashore form of *Asparagus officinalis* L. found on the dunes along the coast of northwestern Europe.

33147. ASPARAGUS TENUIFOLIUS Lam. Asparagus.

A hardy shrub bearing very large, red berries.

Distribution.—The southern part of Europe, extending from France through Italy, the Balkan Peninsula, and southern Russia to Asia Minor.

33148. ASPARAGUS VERTICILLATUS L. Asparagus.

See No. 29121 for previous introduction.

33149. BENINCASA HISPIDA (Thunb.) Cogn.

Variety *macrocarpa*.

33150. BETULA ALBA L. Cut-leaved weeping birch.

Variety *dalecarlica*.

33151. BETULA DAVURICA Pallas. Birch.

Distribution.—A tree, growing up to 60 feet, found in the valley of the Amur River in eastern Asia.

33138 to 33179—Continued.

33152. *BOCCONIA CORDATA* Willd. Flame poppy.
 Variety *microcarpa*. A hardy herbaceous perennial.
33153. *CELTIS AUDIBERTIANA* Spach. Nettle tree.
33154. *CELTIS AUSTRALIS* L.
 See Nos. 2176 and 19505 for previous introductions.
33155. *COTONEASTER HORIZONTALIS* Decaisne.
 See No. 1595 for description.
33156. *COTONEASTER INTEGERRIMA* Medic.
 See Nos. 29666 and 22695 for previous introductions.
33157. *COTONEASTER MICROPHYLLA* Wallich.
 See No. 32934 for previous introduction.
33158. *COTONEASTER MULTIFLORA GRANATENSIS* (Boiss.) Wenz.
 See No. 29969 for previous introduction.
33159. *COTONEASTER PANNOSA* Franchet.
 See No. 32936 for previous introduction.
33160. *COTONEASTER RACEMIFLORA NUMMULARIA* (Fisch. and Mey.) Dipp.
33161. *CRATAEGUS AMBIGUA* Becker. Hawthorn.
 See No. 30289 for previous introduction.
33162. *CRATAEGUS KOROLKOWI* Regel. Hawthorn.
 See No. 30290 for distribution of this species.
33163. *EUONYMUS RADICANS CARRIERI* (Vauv.) Nich.
 A low shrub with ascending and spreading branches.
33164. *FRAXINUS PENNSYLVANICA* Marshall. Red ash.
33165. *GLEDITSIA MACRACANTHA* Desf.
Distribution.—A tree with large spines, closely related to *G. sinensis* Lam. and only known under cultivation.
33166. *JUGLANS PYRIFORMIS* Liebm.
Distribution.—On the slopes of the mountains at an elevation of 6,000 feet in the vicinity of Orizaba in southern Mexico.
33167. *MALUS CERASIFERA* Spach.
Distribution.—A form of *Malus baccata* (L.) Moench probably of hybrid origin; found in Siberia.
33168. *PHYSALIS PHILADELPHICA* Lam.
33169. *PISTACIA LENTISCUS* L. Mastic.
 See No. 9426 for description.
33170. *PRUNUS DOMESTICA* L. Plum.
 Variety *armenioides*.
33171. *PYRUS CANESCENS* Spach. Pear.
 See No. 29973 for previous introduction.
33172. *PYRUS COMMUNIS PYRASTER* L. Pear.
Distribution.—A form of the common pear having fruits the size and shape of a cherry, originating in the northeastern part of Persia.
33173. \times *PYRUS OBLONGIFOLIA* Spach. Pear.
Distribution.—Considered to be a hybrid between *Pyrus amygdaliformis* Villars and *P. nivalis* Jacq.

33138 to 33179—Continued.**33174 to 33179. SOLANUM NIGRUM L.****Nightshade.****33174.****33177. Variety *miniatum*.****33175. Variety *flavum*.****33178. Variety *oleraceum*.****33176. Variety *guineense*.****33179. Variety *villosum*.****33180 and 33181. JUGLANS REGIA L.****Walnut.**

From China. Presented by Mr. Samuel S. Knabenshue, American consul general, Tientsin, China. Received at the Plant Introduction Field Station, Chico, Cal., March, 1912.

Seeds of the following; quoted notes by Mr. Knabenshue:

33180. "This hard-shelled variety grows to the westward of Changli, in this province (Chihli), and Shansi. It appears to grow only in the hill country. The nuts marketed in Tientsin come either from the mountainous region north and west of Peking or from the mountains of Shantung. These nuts came from the western hills at Peking and are very fair samples of the hard-shelled variety."

33181. "This soft-shelled variety was also obtained from Changli. This town lies on the edge of the hill country, and the district around it, so far as can be learned, is the only one producing the soft-shelled nuts. I am unable to obtain any precise information as to the nature of the soil. The hills of the vicinity are evidently of volcanic origin, though extremely ancient in geologic time. The soil, to all appearance, is like that of the Great Plain of China, an alluvial formation, brought down from the loess deposits to the west of Peking. The heavy wind storms to the north, which bring the much-dreaded tornadoes of dust, in the course of centuries must have added materially to the soil of this section of China. The wind brings down from the Gobi Desert a very fine, yellow sand apparently."

33182 and 33183.

From the Philippine Islands. Presented by Mr. O. W. Barrett, Chief, Division of Experiment Stations, Bureau of Agriculture, Manila. Received March 20, 1912.

Seeds of the following; quoted notes by Mr. Barrett:

33182. Ficus sp.

"A small tree, rarely branching. Leaves linear lanceolate, from 1 to 1½ feet in length, dark green, the peculiar fruits being produced in the axils of the leaves. As the plant grows the leaves are shed, with the exception of a number at the top, making the crown of the plant appear not unlike a bird's-nest fern. It should make a very attractive greenhouse subject."

33183. LAGERSTROEMIA SPECIOSA (L.) Pers.

"A small shrubby tree, indigenous to the Philippines, blooming in the spring, when it is one of the most striking plants in the Philippines."

33184. ANNONA CHERIMOLA Miller.**Cherimoya.**

From Los Angeles, Cal. Presented by Mr. Charles F. O'Brien. Received March 21, 1912.

"This cherimoya on my ranch was grown from seed produced by a tree originally brought from Peru by a brother-in-law of a Mr. Miller, who now lives in Hollywood, Cal. The old tree was killed some years ago.

"Mr. Miller's brother-in-law informed him that he found the young tree growing along the bank of a stream in the interior of Peru at a considerable elevation. He stated that the trees grown there grew to large size and produced fruit that sometimes weighed as much as 14 pounds. He also stated that at the time the fruit ripened in that part of Peru it formed the principal article of diet of the native Indians.

"I have seen specimens of the cherimoya of Mexico growing here, but the fruit is not so large as this Peruvian fruit, nor does the tree attain such great size. The foliage is also smaller.

"In handling my tree I have found that it should be vigorously pruned early in the spring. It gives best fruiting results with that treatment.

"These seeds are from the finest fruit borne by the tree last year; it weighed 2 pounds 6 ounces, was perfect in shape, with a very thin skin; meat white and of very fine texture. It was, in fact, the finest specimen I have ever obtained from this tree.

"This particular tree is the finest cherimoya in all southern California, and the finest I have seen anywhere. The fruit is also much superior to that which is now being offered in the market here." (*O'Brien.*)

33185. ACACIA SCORPIOIDES (L.) W. F. Wight.

From Algeria. Presented by Dr. L. Trabut, Algiers. Received March 21, 1912.

"A variety cultivated at Biskra." (*Trabut.*)

33186 to 33188.

From Italy. Presented by Mr. Willy Müller, Nocera Inferiore, Italy. Received March 21, 1912.

Seeds of the following:

33186. AKEBIA LOBATA Decaisne.

See Nos. 24744, 26424 and 30855 for previous introduction.

33187. CUCUMIS MELO L.

Muskmelon.

From Castellammare.

33188. CUCUMIS MELO L.

Muskmelon.

From Nocera.

33189. JUGLANS REGIA L.

Walnut.

From Sorrento, Italy. Procured by Mr. W. B. Fiske, of the Bureau of Entomology, United States Department of Agriculture, stationed at the Gypsy-Moth and Alfalfa-Weevil Laboratory at the R. Scuola Superiore D'Agricoltura, Portici, from Mr. Pasquale D. Luca, head gardener, at the request of Mr. William W. Handley, American consul, Naples, Italy. Received March 22, 1912.

"*Sorrentina.* The trees from which these cuttings were taken were grown by me in ground at Meta di Sorrento belonging to the estate of Dr. Corrado Buggiero. The shoots were all from the same variety and were taken from two trees. The *Sorrentina* is a large and majestic tree with a large crown and great branches while still young, and covered with a clear gray bark which with age becomes split. The leaves are quite large, alternately pennate with 5 to 9 leaflets, and when fresh they have a peculiar odor. The fruit is an oblong drupe and terminates in a rather long point. The pericarp is rather thin and the endocarp is very fleshy." (*Pasquale D. Luca.*)

33190. PHOENIX DACTYLIFERA L.

Date.

From Panjgur, India. Received through Mr. Stuart K. Lupton, American consul, Karachi, India. Received March 23, 1912.

"I am informed that to properly mature dates a steady sustained, hot, dry wind for about 30 days is necessary and that this condition prevails nowhere in the consular district except in the neighborhood of Panjgur." (*Lupton*.)

This is probably the famous *Mozati* date introduced under S. P. I. No. 8762.

33191. *MISCANTHUS JAPONICUS* (Thunb.) Oerst.

From Yokohama, Japan. Purchased from the Yokohama Nursery Co. Received March 23, 1912.

"This has been found in our experimental work to produce a light bulky paper in many respects similar to that made from esparto. The yield of fiber is up to the average of esparto, and there may be areas where the plant can be grown especially for paper making. It thrives on the poorer soils in this region (Washington, D. C.) and has been grown with some success even in Maine; the excessive winter killing here, however, would prevent its becoming a successful crop plant." (*Charles J. Brand*.)

Seeds.

Distribution.—The provinces of Kiangsu, Kiangsi, and Kwangtung in China, and in Japan and the Malay Archipelago.

33192. *TERMINALIA CATAPPA* L.

Katappa.

From Sibpur, Calcutta, India. Presented by Maj. A. T. Gage, Superintendent, Royal Botanic Gardens. Received March 23, 1912.

Distribution.—A tree, often 80 feet high, found in the plains of India and generally cultivated in tropical countries.

33194 to 33201. *Rosa* spp.

Rose.

From Kew, England. Presented by Dr. David Prain, Director, Royal Botanic Garden. Received March 19, 1912.

Cuttings of the following, procured for breeding experiments:

33194. *ROSA BEGGERIANA* Schrenk.

Rose.

Distribution.—A shrub, growing as high as 10 feet, found on mountain slopes from 5,000 to 10,000 feet in elevation from the Caspian Sea and Persia eastward through Turkestan and Afghanistan to Mongolia.

33195. *ROSA WEBBIANA* Wall.

Rose.

Distribution.—Dry slopes of the Himalayas in northern India from Kashmir to western Tibet at an elevation of 5,000 to 13,500 feet.

33196. *ROSA ACICULARIS NIPPONENSIS* (Crepin) Koehne.

Rose.

Distribution.—The slopes of Mount Fujiyama, in Japan.

33197. *ROSA SPINOSISSIMA* L.

Rose.

Variety *hispida*.

33198. *ROSA SPINOSISSIMA* L.

Rose.

Variety *lutea*.

33199. *ROSA CINNAMOMEA MALYI* (Kern) Skeels.

Rose.

(*Rosa malyi* Kern 1869, in *Oesterreichische Botanische Zeitschrift*, vol. 19, p. 325.)

Cuttings of this rose were received under the name *Rosa malyi*. In 1902 this form was referred by Keller (Ascherson and Graebner, *Synopsis der Mitteleuropäischen Flora*, vol. 6, p. 305) to *Rosa pendulina*, which was published by

33194 to 33201—Continued.

Linnaeus in 1753 on page 492 of the *Species Plantarum*. But on page 491 of the same work Linnaeus published the name *Rosa cinnamomea*, which is generally considered to be the same as *R. pendulina*. Keller uses the name *R. cinnamomea* for the species described under that name in 1759 by Linnaeus (*Systema Naturae*, ed. 10, vol. 2, p. 1062). According to present rules of botanical nomenclature, *R. cinnamomea* must be used for the first species described under that name, and our plant being a form of that species, is here placed under it.

Rosa cinnamomea malyi was first discovered by Herr Maly on the slopes of the mountains in Dalmatia, and was by him introduced into cultivation.

33200. *ROSA MACROPHYLLA* Lindl.

Rose.

33201. *ROSA FEDTSCHENKOANA* Regel.

Rose.

Distribution.—A little known species from Turkestan.

33202. ROSA HÆMISPHERICA Herrmann.

Rose.

From Bitton Vicarage, Bristol, England. Presented by Rev. Henry N. Ellacombe. Received March 19, 1912.

Procured for breeding experiments.

33203 and 33204. DIOSPYROS KAKI L. f.

Persimmon.

From Tokyo, Japan. Presented by Mr. T. Watase, Tokyo Plant, Seed & Implement Co. Received March 23, 1912.

Cuttings of the following, quoted notes by Mr. Watase:

33203. "*Uzaemon*. Astringent variety."

33204. "*Myotan*. Late, sweet variety."

"The above cuttings were those with pedicels left from staminate flowers."

33205 to 33234.

From Granada, Spain. Purchased from Mr. Pedro Giraud, at the request of Mr. Walter T. Swingle, Bureau of Plant Industry. Received March 23, 1912.

Quoted notes by Mr. Walter T. Swingle, unless otherwise noted.

"The following collection of grafted plants, rooted cuttings, and scions or cuttings embraces some of the principal varieties of fruits grown in Granada. Dr. Gustav Eisen has shown that many of the so-called Mission varieties of fruits grown in California in the early days really originated in Granada. It is hoped that some of the varieties in the following list will prove to be of considerable value. The shipment was made largely to test the possibility of shipping plants in good order from central Spain to the United States."

33205. CRATAEGUS AZAROLUS L.

Azarol.

"*Encarnado*. The azarol represents a type of fruit whose cultivation has been much neglected in the United States. These fruits, which ripen from August to October in Spain and France, are from a half inch to an inch in diameter or even more, and have a delicious, subacid flavor, with flesh of a melting character. In flavor and texture its fruits resemble loquats in many respects. These plants are grafted on the common hawthorn and are said to grow in all kinds of soil, both dry land and under irrigation. The variety in question is flesh color, supposed to be of Italian origin."

33205 to 33234—Continued.

33206. *POPULUS* sp.

Poplar.

"*Chopo*. This is a remarkable form of poplar commonly grown about Granada, striking because of the almost complete absence of true lateral branches, the stems being clothed with twigs which, as is common in poplars, are sooner or later thrown off by separative layers near the base. Because of this habit of growth, it can be planted very close together. It is said to give an enormous yield of wood, because of its rapid growth and the absence of branches."

"This tree is one of the best suited for forming poplar plantations in humid soil and along the shores of rivers. The poles used in scaffolding are generally made of this species and the wood is that most generally used for the making of boxes for small shipments." (*Pedro Girsud*.)

33207 to 33209. *PYRUS COMMUNIS* L.

Pear.

33207. "*Favorita*. This pear is described as follows: Fruit very large, lemon yellow, flesh buttery, sweet, savory. Ripens the middle of August. A summer pear."

33208. "*Pera de Roseta*."

33209. "*Pera de Aragon*. Fruits large, yellow, flesh very fine, very juicy and sweet, ripening December and January. This is perhaps the pear which is exported all through southern Spain and even to Algeria and Morocco throughout the winter months. This pear, which is said to come from Aragon, is a very broad, short fruit and can be shipped great distances, standing the roughest kind of handling. In fact, the pears are often handled like so much coal."

33210 to 33212. *MALUS SYLVESTRIS* Miller.

Apple.

33210. "*Pero Blanco de Ronda*. In Spain all green apples, especially those of elongated form, are called, not *manzanas*, but *peros*, which has led to considerable confusion on the part of foreigners because of the similarity of this latter word with *pera*, which is pear. Perhaps because of this fact many of the best Spanish apples seem to be relatively little known to the horticulturists of other countries. This variety, the famous *Pero Blanco de Ronda*, often called simply *Pero de Ronda*, is a very delicious apple and one which is well adapted to export trade. It is a winter apple, ripening in Spain in the month of January."

33211. "*Pero Blanco de Dusal*. This is another variety of *pero*, about which no information could be secured except that it is a winter variety ripening in January."

33212. "*Pero Encarnado de Priego*. Another variety which the name would indicate to be flesh colored; said to ripen from November to January. No description could be found of this variety."

33213 and 33214. *CYDONIA OBLONGA* Miller.

Quince.

33213. "*Antequera*. The Spanish quinces are famous for their high quality, and the best are said to come from Antequera."

33214. "*de Antequera*. Probably the same as 33213."

33205 to 33234—Continued.

33215 to 33218. *AMYGDALUS COMMUNIS* L.

Almond.

33215. "*Malagueña*. This is the famous Jordan almond, which is exported so largely from Malaga. I was told at the American consulate that some \$800,000 worth of almonds had been exported from the port of Malaga alone during the year 1911. These exports consist largely of the *Malagueña* variety. Jordan almonds are classified by the wholesale dealers as to number per ounce. They run from 15 to 30 or more per ounce. The English market takes the very large size, the American market taking most of the 30's and other small sizes. Out of 100,000 boxes only three or four hundred would be as large as 15 to 16 to the ounce. This is called the export variety by the cultivators around Malaga, after the Spanish word 'exportacion.' It is grown in very dry situations and is properly speaking a dry-land crop of very great importance. Pedro Giraud, from whom the plants were secured, says of almonds in general that they give best results in warm, dry, rocky, limestone soils."

33216. "*Almendro de Esperanza*. A variety of almond recommended for culture by Mr. Giraud."

33217. "*Almendro de la P.* This is said to be a large, early variety of almond."

33218. "*Almendro del Desmayo*. This is an especially valuable variety of almond for testing on account of its hardiness. Pedro Giraud says: 'The variety of almond *del Desmayo* is the most resistant to frost, which is caused by the peculiar attachment of the flower, which is turned downward, its corolla and sepals protecting it against the action of frost, in this way insuring the fertility of this sort when all other varieties would have their crops destroyed.'

33219 to 33221. *AMYGDALUS PERSICA* L.

Peach.

"As to these three varieties of peaches no definite information was available, but as the Spanish peaches are famous for their quality, any variety which is propagated is likely to be good."

33219. "*Vanqueur*."33220. "*Campiel Amarillo*."33221. "*Tempeanos Junio*."33222 and 33223. *PRUNUS AVIUM* L.

Cherry.

33222. "*Garrafal*. A giant cherry having firm, sweet flesh."33223. "*Garrafal le Grand*. Another large variety of cherry, possibly of French origin. Said to ripen in June."33224. *PRUNUS DOMESTICA* L.

Plum.

"*Ciruela de Fraile*. A variety ripening in June, said to be of excellent quality."

33225. *OLEA EUROPEA* L.

Olive.

"*Gordal* or *Sevillana*. This is the famous variety which yields the large, green, pickled olives so common in America. It is largely cultivated in the zone immediately about Seville, where its culture is said to succeed better than in any other part of Spain. They run from about 70 to 200 per kilo, or about 30 to 90 to the pound. These enormous olives are of beautiful appearance, but by the Spaniards are not considered to be of as good quality as some

33205 to 33234—Continued.

of the other varieties, such as the *Manzanillo*. The *Sevillana* variety is graded very carefully, running 70, 80, 90, 100, and so on per kilo, and this grading requires to be done very carefully, making the olives for the American market much more expensive than for the Argentine and other markets which do not require such an excessively careful grading."

33226. *OLEA EUROPEA* L.

Olive.

"*Hermanos*. This is probably the *Quatro Hermanos* olive as noted by Dr. Eisen in the vicinity of Granada, which variety, as the name indicates, is peculiar in having four fruits borne together, arranged in the form of a cross. Beyond this but little is known as to the variety, which may, however, be of importance, since very good olives are grown in this region."

33227 to 33229. *PUNICA GRANATUM* L.

Pomegranate.

"Since the city and province of Granada get their name from the pomegranate, it is to be expected that this fruit would have attained great perfection in this region. The following collection includes three of the principal varieties as grown about Granada. Mr. Pedro Giraud recommends that they be grown in espalier against a wall, where they can be irrigated a little during the hot, dry Spanish summer. There is a large exportation of pomegranates to England, and a small quantity reaches the United States. These are not shipped from Granada, but from ports in the east of Spain, especially Valencia."

33227. "*Negro monstruoso*."

33228. "*Granado de Jativa*. This is said to be one of the most appreciated varieties in the region of Granada and is said to be without seeds."

33229. "*Granado de Rogises*."33230 to 33233. *FICUS CARICA* L.

Fig.

"The figs of Granada are famous for their abundance and good quality. Dr. Gustav Eisen has shown that the California mission fig came originally from Spain and probably was imported from Granada. It is difficult to imagine a variety better adapted to California conditions, and it is hoped that some of the following will prove equally well suited."

33230. *Albanes*.33231. *Pata Mulo*.33232. *Isabella*.

For description see No. 32878.

33233. *Breval Negra*.33234. *CORYLUS AVELLANA* L.

Hazelnut.

"*Rouge Ronde*. Spain furnishes the bulk of the hazelnuts that enter into the world's commerce, whole regions being given up to this remunerative culture in the north of Spain. It is said to prefer rather light, cool soils and to grow well with more or less shade. The trees are set at short distances apart. From its name, meaning the 'round red,' the variety would seem to be of French origin."

33235. *CARICA PAPAYA* L.

Papaya.

From Philippine Islands. Secured through Mr. Alvin R. Schwab from Mr. J. A. Dunn of Akron, Iowa, by Mr. E. C. Green, in charge, South Texas Plant Introduction Garden, Brownsville, Tex. Received March 22, 1912.

Seeds.

33236 to 33238.

From Buitenzorg, Java. Presented by The Director, Department of Agriculture.
Received March 23, 1912.

Seeds of the following:

33236. CORCULUM LEPTOPUS (Hook. and Arn.) Stuntz.

Seed of this polygonaceous climber were received under the name *Antigonon leptopus* Hook. and Arn. This generic name, used but not technically published in 1837 by Endlicher (*Genera Plantarum*, p. 310), is antedated by *Antigona*, published in 1827 by Velloso (*Flora Fluminensis*, p. 186, vol. 4, pl. 145). As no other name has been suggested for the genus, *Corculum*, the diminutive of the Latin "cor" (heart), is used in reference to the diminutive heart-shaped rose-colored flowers.

Variety *alba*. See No. 19619 for description.

33237. CITRUS DECUMANA (L.) Murray.

Pomelo.

"*Djeroc pandan*."

33238. DRACONTOMELON DAO (Blanco) Merrill and Rolfe.

Dao.

See No. 32336 for previous introduction.

33239. BRASSICA PEKINENSIS (Lour.) Skeels. Pai tsai cabbage.

From Nanking, China. Presented by Mr. Joseph Bailio, University of Nanking.
Received March 20, 1912.

Shantung.

33241 to 33248. SACCHARUM OFFICINARUM L. Sugar cane.

From Alighur, United Provinces, India. Presented by Dr. Parr, Agricultural College. Received March 23, 1912.

Cuttings of the following:

33241. *Saretha*.

33245. *Kinar*.

33242. *Khera*.

33246. *Chiu*.

33243. *Merthi*.

33247. *Mungo*.

33244. *Dhaur*.

33248. *Sonabeki*.

33249. PHRAGMITES KARKA (Retz.) Trin.

From Japan. Purchased from the Yokohama Nursery Co., Yokohama. Received March 26, 1912.

Udono-yoshi. "A perennial grass growing in marshy places. Its roots creep under the ground and shoot up stalks to a height of about 6 feet, bearing panicles at the tops. The stalks resemble small bamboos, being slender, light, and lustrous, and they are used to make blinds. The thickness of the stalk depends on the fertility of the ground. Those growing by seacoasts are slender, flexible, and strong. This grass is planted in watersides to protect mud from being washed away by waves. Its young sprouts are edible. Those produced in Udono—village of Province Setsu—are called Udono-yoshi, and are very famous for their large and long stalks. They are used to make *Shichiriki*, a musical instrument." (*Useful Plants of Japan, Agricultural Society of Japan, 1895, pp. 222-223.*)

See No. 21957 for previous introduction.

33250 to 33255. ARALIA CORDATA Thunb.

Udo.

From Japan. Presented by Prof. Y. Kozai, Director, Imperial Agricultural Experiment Station, Nishigahara, Tokyo. Received March 26, 1912.

33250 to 33255—Continued.

Roots of the following; quoted names and notes by Prof. Kozai:

"Varieties universally cultivated in Kyoto."

33250. "*Yocemon*. Red, early."

33251. "*Hanza*. Late."

33252. "*Fushiata*. Node red, middle."

"Varieties universally cultivated in Saitama, near Tokyo."

33253. "*Shiro*. White, very early."

33254. "*Nakate Uru-Aka*. Rosy, middle."

33255. "*Kan-Udo*. Red, extra early."

33256 and 33257.

From Algeria. Presented by Dr. L. Trabut, Algiers. Received March 27, 1912.

33256. *TYPHA ELEPHANTINA* Roxb.

From Kodjaberi.

"This giant *Typha* is closely related to the rare *T. elephantina* of Java. This *Typha* has leaves which may attain 4 meters in length. It occurs in moist regions, but not in water. The tufts have a remarkable appearance—one would say a field of *Phormium*. The leaves are carinate, thick, but not very solid. It is cultivated for cooperage in Algiers, but the leaves break." (*Trabut*.)

Roxburgh, *Flora Indica*, vol. 3, p. 566, calls this elephant grass and says, elephants are very fond of it.

Distribution.—Marshes throughout India from the northwest to Assam and southward; also in Algiers.

33257. *SACCHARUM SPONTANEUM* L.

From Bona.

33258. CACARA EROSA (L.) Kuntze.

Yam bean.

From Kingston, Jamaica. Presented by Mr. William Harris, Superintendent of Public Gardens. Received March 27, 1912.

"Flowers white. Seeds red. The root is formed of a number of simple cordlike fibers, several feet in length, stretching under the surface of the ground, bearing in their course a succession of tubers.

"The beans are poisonous, but the root affords a very plentiful supply of very wholesome food. The produce of three plants is usually sufficient to fill a bushel basket. The tubers may either be boiled plain, in which state they are a very good substitute for yams and other roots in common use, or they may be submitted to a process similar to arrowroot, and a starch obtained. This starch is of a pure white, and is equal in every respect to arrowroot. To the taste it is very palatable, is easily digested, and is employed for custards and puddings. Even the trash left after obtaining the starch, and which in the preparation of arrowroot is lost, may, when thoroughly dried, be formed into a palatable and wholesome flour.

"A very excellent flour may also be obtained by slicing the tubers, drying them in the sun, and then reducing to a powder.

"This plant is deserving of being more generally cultivated than it has heretofore been. It ought in a great measure to supersede the arrowroot in cultivation. It can be planted at any season of the year, and the roots are fit for digging in the course of four or five months; the return is infinitely greater than that from arrowroot, and the

proportion of starch also is abundant, so that it can be brought to market at so cheap a rate as to admit of being employed by the calico printers in place of potato starch.

"The Kew Bulletin for 1889, page 17, quotes from letters from Dr. Trimen, Director of the Botanic Gardens in Ceylon, pointing out that the pods when young are not poisonous, but may be eaten like French beans. He wrote: 'They are quite new to Ceylon * * *. The young pods served like French beans are an admirable vegetable, tender and sweet * * *. What constitutes their superiority over the ordinary French beans is the absence of any fibrous string along the sutures of the pod. The large size is also an advantage; they are often 10 or 12 inches long.'

"In Jamaica the seeds are generally sown in March or April. But they can be sown at any time. At Hope Gardens seeds were sown in September. The pods are ready for use as French beans seven months after sowing, and when pods are quite ripe, nine months after sowing, the yams are fit to dig. From one seed sown at Hope Gardens five yams were dug weighing altogether 14 pounds. They generally vary in size from 1 foot to 18 inches long and 4 to 6 inches in diameter." (*Bulletin No. 44 of the Botanical Department of Jamaica, June, 1893, p. 4.*)

33259 and 33260.

From Para, Brazil. Presented by Mr. Walter Fischer, Campo de Cultura Experimental Paraense. Received March 29, 1912.

Seeds of the following, taken from fruits brought in by Mr. Fischer:

33259. *LECYNTHIS USITATA* Miers.

Sapucaia nut.

"This is a large tree of the monkey-pot family, native of forests in the region of the Amazon. It has large, urn-shaped fruits of a hard, woody texture, about 6 inches in diameter, with lids measuring about 2 inches across. When ripe the lid separates from the capsule, emitting a sharp sound, which when heard by the monkeys is a signal that the nuts are falling and a scramble and fight to be the first to obtain them ensues; on this account few are left for the trader, and the export is consequently small. The common name of monkey-pot is applied to the capsule when empty." (*Dictionary of Popular Names of Economic Plants, John Smith, 1882.*)

See No. 25435 for previous introduction.

33260. *THEOBROMA GRANDIFLORA* (Willd.) Schum.

Cupuaçú.

"This is a very common fruit here. Its odor and taste may be somewhat nauseating to some, at least if received in too large quantities, but it is really a very luscious fruit. It is used here considerably for making jellies and preserves, which have an aftertaste which may not be liked at first, but which, like that of the guava, when once acquired would become very popular." (*Fischer.*)

Distribution.—Damp shady places in the forests of the Amazon Valley in the provinces of Amazonas and Para, in Brazil.

33261. *EUGENIA* sp.

From Para, Brazil. Presented by Mr. Walter Fischer, Campo de Cultura Experimental Paraense. Received March 29, 1912.

"This is a small-sized tree about 6 inches in diameter and 20 feet high. The fruit is bright red like a wild goose plum and of the same size. The peel or rind is somewhat thick, but edible like the soft juicy pulp that surrounds the one or two large hairy seeds; the flavor is slightly resinous and also suggests strawberry. It makes a good sauce when stewed and is also very good raw." (*Fischer.*)

33262. STENOLOBIUM SAMBUCIFOLIUM (H. B. K.) Seemann.

From La Mortola, Ventimiglia, Italy. Presented by Prof. Alwin Berger, Director, Botanic Gardens. Received March 29, 1912.

Distribution.—An erect shrub, closely related to *Stenolobium stans* (L.) Seemann, from which it differs in having a white-lobed corolla. Found in the vicinity of Montan, Peru, at an elevation of 8,000 feet.

33263. TELFAIRIA PEDATA (Smith) Hook.

From Zanzibar, East Africa. Presented by the Director of Agriculture, Zanzibar Government. Received March 29, 1912.

"A cucumberlike vine, growing over trees of considerable height throughout tropical Africa. The fruit sometimes attains a weight of 60 pounds and contains a large number of oily seeds about 2 inches in diameter. The oil from these seeds is said to be largely used for culinary purposes by the natives. The flowers are of two forms of varying shades of lavender and are several inches across." (*S. C. Stuntz.*)

See No. 23731 for previous introduction.

33264. SALSOLA ARBUSCULA Pallas.**Saxaul.**

From Algiers, Algeria. Presented by Dr. L. Trabut. Received March 29, 1912.

"Saxaul, originally from Turkestan, sown in the Sahara at El Oud in 1895 and in 1900. It flourishes vigorously in the dunes. Seed collected at El Oud, south of Biakra." (*Trabut.*)

See Nos. 24555 and 28976 for previous introductions.

33266. CUCUMIS MELO L.**Muskmelon.**

From Persia. Presented by Mr. C. A. Douglas, American Mission, Teheran, Persia. Received March 22, 1912.

"Persian muskmelon. Found in Persia only at the town of Avonikaf, 50 miles from Teheran. An extremely hot climate and a desert country watered from mountain streams. The soil is a red clay, mixed with much gravel. The melon seeds are planted along the little ditches where the water may reach them weekly. They are not sown until late in May. The melon matures late in October and can be kept until December in a dry place.

"The melon is in size and shape something like a small watermelon. On the outside it is dark green, rough, with coarse, light-colored markings. The flesh is yellow, shading into green, quite firm in texture, yet full of water. In taste, it is remarkably sweet and of a peculiar luscious flavor. It is surpassed by no other melon found in this land of the melon, so that even the natives are willing to pay 20 cents apiece for them." (*Douglas.*)

33268. LANGUAS GALANGA (L.) Stuntz.**Galangale.**

From Peradeniya, Ceylon. Presented by Mr. H. F. Macmillan, curator, Royal Botanic Garden. Received March 9, 1912.

A zinziberaceous plant from the eastern Tropics, whose aromatic root furnishes the galangale used by the natives for indigestion.

See Nos. 32036, 32037, and 32837 for previous introductions.

33270. MELILOTUS OFFICINALIS MICRANTHUS Schulz.

From Krasny Koot, Samara, Russia. Collected by Mr. W. Bogdan. Presented by Dr. R. Regel, Bureau of Applied Botany, St. Petersburg, Russia. Received March 27, 1912.

Distribution.—Southeastern Russia and Turkey, and eastward through Armenia, and Persia to Turkestan.

33271. MYRTUS ARAYAN H. B. K.

Arayan.

From Rio Verde, San Luis Potosi, Mexico. Presented by Mr. F. Foex, Director, Agricultural Experiment Station of Rio Verde, through Mr. William A. Taylor, Assistant Chief, Bureau of Plant Industry. Received March 8, 1912.

"These seeds are from a fruit tree of the State of Jalisco. This fruit is well appreciated by young boys, and, above all, by young girls, but not by older people, because they are acid. But they are delicious—First, cooked with sugar; second, dried in sugar powder; third, in sauces for puddings, etc.; fourth, in sirups. These fruits are very small, but when the young trees are 18 months old they can be budded with larger and better varieties." (Foex.)

See No. 30499 for previous introduction.

33272 to 33277.

From Valencia, Spain. Presented by Mr. R. Frazer, jr., American consul, at the request of Mr. Harry B. Chase, Riverside, Cal. Received March 29, 1912.

Seeds of the following; quoted notes by Mr. Frazer:

33272 to 33274. CITRULLUS VULGARIS (L.) Schrad.

Watermelon.

"The watermelon of this district, and indeed of all Spain, appears to be a fixed species that has undergone very little modification for centuries. The varying degrees of color and different percentages of sugar that distinguish the pulp of fruit grown in different localities in Spain appear to depend almost entirely on soil conditions rather than varieties, and the Valencia watermelon still differs little from similar fruit grown in northern Africa. It does not attain very great size, but has a remarkably thin rind and highly colored meat, and is of superior quality.

"The principal pests from which melons of all kinds suffer here are mildew, scale, and snails. The scale, which is said to belong to the family of the rose scale, is the most difficult to combat successfully, especially when dull, foggy, warm weather conditions favor its rapid propagation. The dry, parching winds that blow at irregular intervals during the summer from the semiarid interior of the country effectively arrest the progress of this scale and if continued two or three days will exterminate it altogether. Snails are dealt with in a very practical and economic way by turning flocks of ducklings into the melon plantations affected."

33275 to 33277. CUCUMIS MELO L.

Muskmelon.

33275. "*Bronceado*. This melon is oval or slightly conical in shape, with very thick meat and small seed cavity."

33276. "*Negro*. This melon is of a very dark unchanging-green color, of an elongated oval or cylindrical shape and unusually large, weighing 9 to 16 pounds."

33277. "*Bronceado* and *Negro* seed mixed."

"These are the genuine winter melons of this zone, they are by far the best varieties and receive the greatest care in selection and cultivation. Both at their best are wonderfully fine, and probably nothing superior of their kind can be produced in any part of the world.

"The fame of the fine winter melons grown in this district, of which 12,000 to 15,000 tons are exported annually, has extended over the

33272 to 33277—Continued.**33275 to 33277—Continued.**

greater part of Europe. Small shipments have been made in recent years to New York and Boston, but the total lack of cold-storage facilities in ships visiting this coast and the consequent very large percentage of deterioration in transportation has generally rendered such experiments unprofitable.

"The Valencia system of melon raising requires seed beds and transplanting. The seeds are planted in the former in clusters of five or six on a layer of animal manure wrought into a thick paste with the addition of water, each cluster being deposited in slight depressions in the surface about 8 or 9 inches apart. The bed is then covered with a light sprinkling of dry, pulverized manure which is kept moist by occasional spraying with water. Transplanting takes place when the two lateral branches of the plant are thrown out and the tip of the central growth is just appearing. The more delicate plants are discarded and only the healthiest and most vigorous utilized.

"In preparing the soil for transplanting, the desired porousness is attained here by mixing with it the sea sand used as hog bedding, to which is added fertilizer in the proportion of 1 sack of ammonia sulphate, the favorite nitrogenous fertilizer in this region, to 10 sacks of the sand bedding. The rows are separated from 6 to 7 feet, and the distance between each plant is 30 to 36 inches. Irrigation in the absence of rain is given at 8-day intervals.

"In the Alicante district, a little to the south of this, the seed are planted definitely in the open in pits about a yard apart in which organic manure has been mixed with the soil.

"It is very difficult to obtain selected melon seed true to variety on the open market in this country. Each farmer reserves his own seed by a very practical method of selection, as only the seeds of fruit distinguished at the family table by its sweetness, flavor, and thickness of pulp are set apart for future planting or exchange with neighboring farmers. This process of selection continued through a succession of years appears to be remarkably successful, attaining such uniformity and high quality of product that it is not unusual to find a whole plantation without a single flavorless specimen among its crop. The smallness of Valencia farms, however, occasionally proves an obstacle in selecting and preserving the purity of varieties, as the proximity of inferior stock may easily nullify the care and labor of the most intelligent farmer in melon raising.

"Winter melons are harvested in the early fall and are suspended in loops of esparto cordage from nails in the beams of roofs and lofts, where they keep with but little deterioration for six months or more."

33278. CLEMATIS sp.

From Tangier, Morocco. Procured by Mr. Walter T. Swingle, of the Bureau of Plant Industry, from Mr. T. Goffart, of Tangier. Received March 25, 1912.

"Seeds of an interesting species growing abundantly in Mr. Goffart's garden. I think it would be interesting for trial in Florida and California and perhaps with protection even as far north as Washington." (Swingle.)

BOTANICAL NOTES AND PUBLICATION OF NEW NAMES.

- 32399.** *CHAETOCHLOA COSTATA* (Roxb.) Skeels.
32430. *RYTILIX GRANULARIS* (L.) Skeels.
32435. *MNESITHEA EXALTATA* (L.) Skeels.
32609. *VIGNA CYLINDRICA* (Stickman) Skeels.
32613. *SYNTERISMA CONSANGUINEA* (Gaud.) Skeels.
32795. *CALLISTEMON CITRINA* (Curtis) Skeels.
32924. *CAJUPUTI CUTICULARIS* (Labill.) Skeels.
32928. *CAJUPUTI PULCHELLA* (R. Brown) Skeels.
32929. *CAJUPUTI WILSONI* (Mueller) Skeels.
32968. *TECOMA PANDORANA* (Andrews) Skeels.
32970, in note. *TRITOMA MACOWANI* (Baker) Skeels.
32971. *TRITOMA NATALENSIS* (Baker) Skeels.
32972. *TRITOMA NELSONI* (Masters) Skeels.
33061. *SOPHORA DAVIDI* (Franchet) Skeels.
33199. *ROSA CINNAMOMEA MALYI* (Kern) Skeels.
33236. *CORCULUM LEPTOPUS* (Hook. and Arn.) Stuntz.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 283.

WILLIAM A. TAYLOR, *Chief of Bureau.*

CEREAL EXPERIMENTS IN THE TEXAS PANHANDLE.

BY

JOHN F. ROSS, *Farm Superintendent,*

AND

A. H. LEIDIGH, *Formerly Scientific Assistant,
Office of Cereal Investigations.*



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., January 15, 1913.

SIR: I have the honor to transmit herewith a manuscript entitled "Cereal Experiments in the Texas Panhandle," prepared by John F. Ross, Farm Superintendent, and Arthur H. Leidigh, formerly Scientific Assistant, Office of Cereal Investigations, under the direction of Carleton R. Ball, Acting Cerealist in Charge, and to recommend its publication as Bulletin No. 283 of the series of this Bureau.

This paper presents the results of extensive experiments with cereals begun in 1903 at Channing, Tex., and continued since 1906 at Amarillo, Tex. The results of less extensive experiments conducted cooperatively at Chillicothe and Dalhart, Tex., are also included.

The transition from ranch and range to farm and crop has been steady in recent years. As the conditions under which crops must be grown in this area are severe compared with those to which most of the settlers have been accustomed in more humid areas and at lower elevations, the demand for information concerning adapted cereals and methods of cereal production in the Panhandle has been and still continues to be very insistent. It is thought that this paper will supply much of the desired information.

The Office of Cereal Investigations desires to express herein its appreciation of the hearty cooperation shown by the Capitol Freehold Land & Investment Co. on its headquarters ranch at Channing through its representative, Mr. Walter Farwell, and by the Chamber of Commerce at Amarillo, Tex., through its various secretaries.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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CEREAL EXPERIMENTS IN THE TEXAS PANHANDLE.

INTRODUCTION.

In the fall of 1903 the Office of Cereal Investigations of the Bureau of Plant Industry began definite experimental work in the Texas Panhandle. This was done in response to an increasing demand for information on cereal crops and cropping methods adapted to that general region. The demand came partly from farmers recently settled in the region and partly from the owners of large areas of land situated therein, which they wished to sell profitably in small tracts for farms. Some interest was also manifest among ranchers who desired to grow feedstuffs for their herds.

PAST AND PRESENT CONDITIONS IN THE PANHANDLE.

The conditions then existing or which had existed in the immediate past were those which formerly obtained over the entire Great Plains area. The land was occupied by immense cattle ranches, used only for grazing purposes. The usually dense growth of short but nutritious grasses, chiefly buffalo grass and blue grama, furnished both winter and summer pasturage for countless numbers of beef cattle, which had no other feed from weaning time to marketing. Under this system, from 15 to 40 acres of grazing land were required for each animal, depending on the nature of the grass cover, the character of the season, and the time of year.

In the half-dozen years previous to 1903 this system had been gradually changing. Overstocking the range had resulted in heavy losses during seasons of drought and in severe winters. A call for feeding crops suited to the plains was coming from ranchers. The demand for new, cheap lands for homes and crop production was increasing. The large ranches were being divided and portions sold for farms. This process is still going on throughout the range country.

Most of the settlers come from the more humid States of the Mississippi Valley area, where conditions are almost entirely different. Some of them bring the proceeds of high-priced lands and

invest heavily; others come with only meager equipment and financial resources. None of them have knowledge of the crop varieties or cropping methods most likely to be successful under the rigorous conditions prevailing on the high, dry plains. But few are helped and many are injured by the partial data and misinformation so commonly sent out to inquirers by land-selling agencies. Few settlers can afford to lose their crops during the first year or two in a new country, and none of them are equipped to discover proper crops and methods by experiment. This is, however, the proper service of the Federal Department of Agriculture and the State experiment stations.

LOCATIONS OF THE EXPERIMENTAL WORK.

It was under the conditions outlined briefly in the foregoing paragraphs that experimental work was undertaken in the Texas Panhandle. Investigations began on August 20, 1903, when the junior writer was assigned to the work in that region. Cooperation was effected with the management of the Capitol Freehold Land & Investment Co., because of their desire to obtain feed grains for their horses and a part of their cattle.

The principal experiments were conducted on the XIT ranch of this company at Channing, Tex., from October 10, 1903, to the end of the cropping season of 1906, and at Amarillo, Tex., after that date. In the fall of 1905 part of the work was transferred to farm No. 1 at Amarillo, where a much broader plan of experimentation was adopted for 1906 and the following years. The year 1906 being the first one at Amarillo and the final one at Channing, the tests were arranged so that those at Channing were largely with the most successful varieties as indicated by the results up to that time. The Channing data for 1906 therefore cover a much smaller number of varieties and deal more with cultural methods and results on larger plats.

The success attending these early operations was so marked that the work expanded rapidly, and other offices of the Bureau of Plant Industry availed themselves of the opportunity to conduct experiments at Amarillo in cooperation with the Office of Cereal Investigations. In 1908, farm No. 2 at Amarillo was obtained and equipped to continue the work which was then being closed on farm No. 1, because, owing to its proximity to the growing city, a renewal of the lease could not be had. The actual transfer of the work to the second farm was made between the cropping seasons of 1909 and 1910. The conditions existing there are treated briefly after the consideration of the experiments at Channing and on the first Amarillo farm.

From the standpoints of climate and crop production, the points of operation are representative of almost all the Texas Panhandle and also of a large part of eastern New Mexico and western Oklahoma. The area contains about 25,000 square miles; the experiments were planned to benefit the settlers throughout this region.

NATURE OF THE EXPERIMENTS.

The lines of experimentation which were pursued included the introduction, comparison, and improvement of varieties of cereal crops, tests of soil tillage, seeding and cultivation methods, and a study of crop rotations to determine those best adapted to profitable crop production and soil improvement. Some years after the work was begun the tillage and rotation experiments of a general nature were placed under the charge of a newly created office of the Bureau of Plant Industry, designated as Dry-Land Agriculture. The experiments so transferred, as well as those conducted since by that office, as also experimental work conducted cooperatively with other offices of the Bureau, are presented here simply as parts of the work conducted at the Amarillo Cereal Field Station.

After the work of the Office of Cereal Investigations was started in the Panhandle two stations were established for work in that region by other offices of the Bureau of Plant Industry. One of these is a cooperative forage-testing station at Chillicothe, Tex., maintained by the Office of Forage-Crop Investigations and the State of Texas. The other is a farm of the Office of Dry-Land Agriculture at Dalhart, Tex. Varietal tests of grains have been conducted cooperatively on a small scale at both points. The results obtained and the conditions existing at the time are treated briefly in this bulletin.

GENERAL PHYSICAL DATA FOR THE PANHANDLE.

LOCATION.

Strictly speaking, the "Panhandle" is the designation applied to that part of northwestern Texas which extends northward from the main body of the State. In common practice, however, this term is usually applied to the entire northwestern part of the State, including the so-called "Staked Plains." The word is here used in the broader sense. Figure 1 is a sketch map of this region. No definite eastern or southern boundary for the Panhandle has ever been fixed, though the eastern boundary is generally held to be the escarpment locally known as the "cap rock," which roughly approximates the line of the 2,000-foot contour. The results given herein are applicable to all the region lying above the level of 2,000 feet and to a

tion reached is about 4,800 feet in the extreme northwest, while the southeastern border has an altitude of only 1,500 to 2,000 feet. East of the nearly level high plains is a rough, broken area where the cap rock is worn through and erosion is more rapid. Eastward still, below the cap rock, the country is rolling.

Drainage is eastward through the tributaries of several rivers, among them being, from north to south, the Cimarron, Canadian, Red, Pease, Brazos, and Colorado. In the high plains, above the cap rock, these streams tend to form canyons, the most notable being that of the Red River from Canyon, in Randall County, eastward for 60 miles.

SOIL.

The soil varies from a light sand in some parts to a heavy clay or adobe in others. The clay soil predominates. The sandy soil is

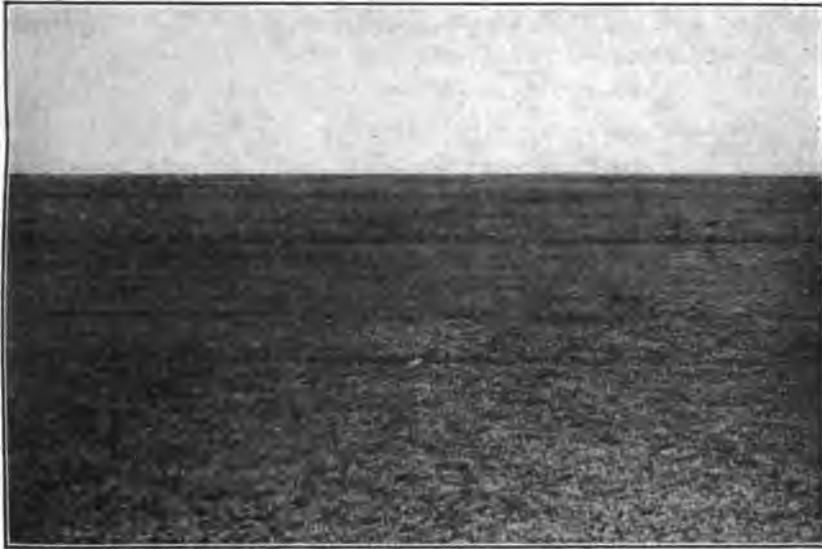


FIG. 2.—Site of the Amarillo Cereal Field Station in 1905, before the experiments were begun.

covered with bunch grasses, while the clay soil is covered with buffalo, curly-mesquite, and blue-grama grasses. Figure 2, reproduced from a photograph of the site of the first experimental farm at Amarillo before work was begun, shows the nature of the country and the character of the vegetation on the clay-loam soil there. These soils are all quite fertile, judging from their power to produce crops when there is sufficient moisture. They are, however, very deficient in humus, owing to the scanty growth of the native vegetation. This lack of humus in the soil lessens its capacity to absorb and retain the moisture which falls upon it. It also leaves the soil

in a condition to become compact and to bake readily after heavy rains.

CLIMATIC CONDITIONS.

No climatic data were available at Channing when the first experimental work was started there. The United States Weather Bureau has conducted an observatory at Amarillo since 1892, and there were disconnected records at two Army posts covering an earlier period. These records and a careful consideration of the native vegetation were of much value in choosing the general types of the various crops with which to begin work.

The principal climatic features of the Panhandle are a limited annual rainfall of irregular seasonal distribution with a great loss of water due to run-off during torrential showers, a relatively low atmospheric humidity, a high average wind velocity, a very high rate of evaporation, and violent fluctuations of temperature accompanied by cool nights in all the district except the lowest parts to the east and south.

RAINFALL.

The average annual rainfall for the 20 years from 1892 to 1911, inclusive, at Amarillo is 21.41 inches, three-fourths of which comes during the growing season, from April to September, inclusive (Table I).

TABLE I.—*Monthly precipitation, in inches, at Amarillo, Tex., for the 20 years from 1892 to 1911, inclusive.*¹

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual.	Mean an- nual.
1892.....	0.42	0.57	2.10	0.21	2.70	1.49	1.85	1.93	0.24	2.85	0.16	1.08	15.00	.....
1893.....	.09	2.03	Trace.	.16	2.19	2.03	2.05	2.67	5.27	.03	.28	.43	17.23	16.42
1894.....	.02	1.15	.05	.85	1.30	3.59	1.82	3.41	2.41	.39	.00	.82	15.81	16.21
1895.....	1.60	1.92	.16	1.31	1.78	6.84	2.88	3.87	.57	2.26	.81	.79	24.79	18.36
1896.....	.76	.41	.21	1.95	2.20	2.31	7.04	.63	2.45	3.09	.35	2.88	24.28	19.54
1897.....	2.26	.65	.47	1.08	4.44	2.32	2.16	2.71	.78	1.63	.08	.63	19.16	19.48
1898.....	.86	.82	.35	.98	3.52	4.81	3.88	4.03	.48	.41	.34	2.06	22.55	19.91
1899.....	.29	.07	.17	.23	3.12	4.45	6.96	.51	6.09	1.15	3.24	1.11	27.39	20.85
1900.....	.59	.47	.48	5.47	4.53	1.94	3.21	.83	5.25	1.58	.08	.07	24.40	21.24
1901.....	.03	.48	.02	4.90	5.99	.82	1.56	3.03	2.19	3.26	2.00	.04	24.42	21.56
1902.....	.04	Trace.	.54	1.83	9.14	2.01	1.45	2.42	.95	1.74	2.24	.55	23.11	21.70
1903.....	.12	2.93	.26	.90	1.79	2.83	3.38	4.67	.82	2.58	.00	Trace.	20.28	21.58
1904.....	.16	.08	Trace.	.63	2.88	5.53	2.48	4.69	3.55	.44	.20	.69	21.33	21.56
1905.....	1.00	1.52	2.32	4.52	6.16	2.19	3.76	.63	3.08	.30	5.09	1.45	32.32	22.33
1906.....	.41	.51	.64	3.23	1.18	2.07	2.90	6.76	1.96	2.49	2.58	.19	24.82	22.80
1907.....	1.11	.24	.02	1.25	.99	1.97	1.49	6.20	.91	1.79	.66	1.46	18.09	22.19
1908.....	.26	.72	Trace.	1.99	3.55	1.73	5.40	2.75	1.88	.40	.51	.00	19.05	22.04
1909.....	.07	.28	1.25	.50	1.08	4.72	3.63	.87	2.19	1.18	3.25	.54	19.59	21.90
1910.....	.05	.17	.34	.59	2.99	.66	3.57	2.19	.05	.26	.28	Trace.	11.15	21.84
1911.....	.13	2.88	.50	2.76	5.88	.20	3.85	2.97	.83	.84	.94	.95	22.73	21.41
Average.	.51	.89	.51	1.76	3.37	2.73	3.27	2.89	2.09	1.43	1.15	.78	21.41	.....

¹ Data furnished by the observer of the U. S. Weather Bureau, Amarillo, Tex.

The seasonal rainfall is sometimes very irregular in its distribution, both as to time and locality. The monthly totals of rainfall often give a wrong idea of moisture conditions to a person unfamiliar with the country. The following not infrequent case will serve to illustrate: A heavy rain falls the first part of one month, the total quantity about equal to the average precipitation for that month. Then a period of drought follows, no rain falling for six or seven weeks, the drought finally being broken by heavy rains at the end of the second month, closely approximating the average for that month. Thus, the monthly averages show the normal rainfall, while in reality a severe drought has existed during the greater part of the period covered. This will be better understood by a close examination of the daily records in Table II.

TABLE II.—Daily and monthly precipitation, in inches, at Amarillo, Tex., for the years 1905 to 1911, inclusive.¹

1905.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		0.10		1.09				0.09		Trace.		
2		.04	Trace.					.21		Trace.		Trace.
3		.05		.38								
4		.04		.22							1.01	
5					0.01				0.64			
6		.38				Trace.		.05				
7			0.60			0.33	Trace.		.81			
8			.10		Trace.	.88	0.41		.69		1.84	
9	0.20				Trace.				.94		1.39	
10	.40		.02									
11	.34	.04	Trace.	Trace.				.09			Trace.	
12	.01	.09	Trace.									0.97
13						.71		.15				.18
14	.02		.30	.10								
15			.40					.03				
16												
17	Trace.	.88	.19							0.02		
18		.22	Trace.	.56	.21							
19							.56					
20					1.00		.16					
21			.21		.46	.19	.86				.03	.15
22				.12		.04	.30				.54	.16
23		Trace.	Trace.	1.24	.21	.01	1.16			Trace.	.24	
24	.01			.41	.36		Trace.			.15		
25							Trace.					
26					3.86		.18					
27					.36					Trace.	.01	
28				.35			Trace.				Trace.	
29				.05		.03	Trace.					
30					.02		.04			.13		
31	.02		.80		.03		.09					
Total.....	1.00	1.53	2.62	4.52	6.52	2.19	3.76	.65	3.08	.30	5.09	1.45

¹Data furnished by the observer of the U. S. Weather Bureau, Amarillo, Tex.

TABLE II.—Daily and monthly precipitation, in inches, at Amarillo, Tex., for the years 1905 to 1911, inclusive—Continued.

1906.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.16					0.01						0.19
2	.07					.17	0.02	0.17	0.09		0.02	Trace.
3	.03			0.35		.84		Trace.	.94			
4	.08	Trace.		.98				.11				
5					Trace.					0.76		
6				Trace.	0.03							
7				.25	Trace.		Trace.	4.05				
8	Trace.						.50	.37				
9	.05					.35	.09	Trace.				
10	.02				.04	Trace.	.04	.20				
11		Trace.	Trace.	.07	.68	Trace.	.34		.04			
12		0.50		.07	Trace.	Trace.	.18					
13		.01			Trace.	.42			.01	.22		
14			0.02		.02		.15		.35	.55		
15				Trace.	.01		.07			.02		
16			.04	.45			.61					
17				Trace.		Trace.	.01		.06	.02	.03	Trace.
18				Trace.			Trace.		.31		.63	
19				.68			.14			Trace.	.71	
20					.01					Trace.	.06	
21					Trace.				Trace.	.39		
22			.01						.19	.53		
23			Trace.		.54			.21			Trace.	
24			.13				.66	.73			Trace.	
25			.05				.06	.92			.23	
26						.28		.03				
27			.37				.64				Trace.	
28			.02	Trace.							.45	Trace.
29				.38							.27	
30							Trace.				.13	
31												
Total.....	.41	.51	.64	3.23	1.18	2.07	2.90	6.76	1.96	2.49	2.58	.19

1907.

1							0.70	0.03				
2				Trace.	Trace.		.03	1.42		0.02		
3		Trace.				0.32		.14	0.21	.65		
4				0.29				.19				
5				Trace.								
6					0.02	.05						
7					Trace.					.05		
8	0.85				Trace.							
9	Trace.		Trace.		.34				.68			
10							.41				0.01	
11											.02	
12	.06					Trace.	.01					
13					Trace.							
14					.02	Trace.	Trace.					
15							Trace.					
16	.03						Trace.					
17	Trace.					1.27					.01	
18	.05				Trace.	.09				Trace.	.05	
19	.01			.04				.41	.02	.03	.57	
20				.28		.24		.07		.07		
21				.4		Trace.		1.47		.25		
22				.04	.03			2.30				
23					.05							
24	.02					Trace.				.54		
25	.03						Trace.			.02		
26	.03						.26					
27		0.24	Trace.				.04					
28			0.02		.14		.04			.02		
29				.11	.17							
30	.04			.01	.19			.01	Trace.			
31					.03			.16		.14		
Total.....	1.11	.24	.02	1.25	.99	1.97	1.49	6.20	.91	1.79	.66	

TABLE II.—Daily and monthly precipitation, in inches, at Amarillo, Tex., for the years 1905 to 1911, inclusive—Continued.

1908.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.							1.07		0.74			
2.	0.02							0.82	.05			
3.	.20	0.01										
4.		Trace.		0.01						0.15		
5.	Trace.											
6.				Trace.		0.42	.01					
7.						.34	.18					
8.			Trace.									
9.				.15		Trace.						
10.		.01										
11.		.10		Trace.			Trace.				0.01	
12.							Trace.				.04	
13.		.12					.10	.77			Trace.	
14.		.48						Trace.	.23			
15.	.04			.62								
16.				.09	0.46				.15			
17.							.54	Trace.				
18.							.02			Trace.		
19.				1.03			.36			.15		
20.								.11				
21.							Trace.	.48	Trace.	.10		
22.		Trace.			1.81							
23.					1.05		Trace.					
24.					Trace.	.35						
25.									.32			
26.								.25	.18			
27.						Trace.	1.13	.32	.16		.09	
28.						.58					.36	
29.			Trace.	Trace.			.04				.01	
30.			Trace.		.19	Trace.	.60					
31.							1.35	Trace.				
Total....	.26	.72	Trace.	1.90	3.55	1.73	5.40	2.75	1.83	.40	.51	

1909.

1.	Trace.					Trace.	1.13					
2.	0.01					0.10						
3.							.02	0.10				0.01
4.		0.02					Trace.	.06	0.47			.12
5.		.02						.04	.20			
6.						Trace.	.67		Trace.			Trace.
7.						.20		.32	1.49			
8.			0.07	0.07	0.04	Trace.	.82	Trace.		0.04		Trace.
9.							.20	.34				
10.	Trace.					.20						
11.	.06		.44			.34						
12.			.20	Trace.		.08			.03		0.99	
13.		Trace.				.88		Trace.	Trace.		.12	
14.		Trace.				.18		Trace.			Trace.	Trace.
15.						.01	.01	.01			.24	
16.					Trace.	Trace.						
17.										.92		.36
18.		.24							Trace.	.21		.05
19.			Trace.		.27		Trace.	Trace.		.01		Trace.
20.		Trace.		.18	.60	1.08		Trace.				
21.				.06		.34						
22.				.11	.05	Trace.						Trace.
23.		Trace.		Trace.	.03							
24.			Trace.		.03	.31						
25.						.65	.10					
26.					.05	.25	.63					
27.											.57	
28.											.98	
29.											.35	
30.			.03	.30	.01	.10						
31.			.54									
Total....	.07	.28	1.28	.50	1.08	4.72	3.63	.87	2.19	1.18	3.25	.54

TABLE II.—Daily and monthly precipitation, in inches, at Amarillo, Tex., for the years 1905 to 1911, inclusive—Continued.

1910.												
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.						Trace.	0.21					
2.							.01					
3.	Trace.	Trace.			0.57			0.67	Trace.			
4.	0.03			0.10	.31							
5.					.02	0.01	.05	.02			0.27	
6.						.02	.07	.18				
7.					Trace.							
8.							.32					
9.				.22			2.05	.64				
10.							.02	.18				
11.	.01								Trace.	0.02		
12.	.01			Trace.	.26	.20		Trace.				
13.				Trace.	.03	.02			Trace.			
14.	Trace.			Trace.	.01	.77		Trace.	Trace.		.01	Trace.
15.			0.06	.15				Trace.	.19			
16.		0.17				Trace.			.01			
17.			Trace.		Trace.	.17		Trace.				
18.			Trace.							.06		
19.										.18		Trace.
20.						.60						
21.					.05	.01			Trace.			
22.					.01							
23.		Trace.				Trace.						
24.						.07		.26	0.06			
25.			Trace.		Trace.	.25		.02				
26.			Trace.			.20						
27.				.13		.28						Trace.
28.					Trace.							
29.												
30.							.84	.02				Trace.
31.												
Total.....	.05	.17	.34	.59	2.99	.66	3.57	2.19	.05	.26	.28	Trace.

1911.												
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.	0.05							0.20		0.13	0.08	
2.				Trace.			0.01				.33	
3.				Trace.			Trace.			Trace.	Trace.	
4.		Trace.		0.01	Trace.		.01			Trace.	Trace.	
5.									Trace.	Trace.	.12	
6.						Trace.	.32					
7.							.04		Trace.			
8.												
9.						0.11	.03		0.13			0.01
10.		0.16		Trace.								
11.							.06					
12.					Trace.		.32					
13.					0.40		.42					.02
14.					.15		Trace.					Trace.
15.	Trace.				.01				.41			
16.		.46					.03					
17.	.07	1.61				.08	.50					
18.		.22							Trace.			.04
19.		.15					.68		Trace.			.76
20.			0.40		.04		.47		.01	.07		.07
21.			.10				.49	.07		Trace.		
22.		Trace.		.04			.12	.66				
23.	.01			2.61				2.02				
24.				.07								
25.				.02		Trace.						
26.				.01	.61					.19	.06	Trace.
27.		.03				.01	.16	Trace.		.17	.35	
28.	Trace.	.20			1.64		.03	.02		.14		
29.					2.90		.14			.14		Trace.
30.					.13				.28			.08
31.							.02					
Total.....	.13	2.88	.50	2.76	5.88	.20	3.85	2.97	.83	.84	.94	.95

Many of the rains during the summer are very local in character, consisting of heavy showers at different points with stretches of almost no rainfall between. To illustrate the variation in rainfall at near-by points, Table III gives a comparison of the rainfall at the United States Weather Bureau observatory and at the cereal testing station at Amarillo, Tex., for seven months during the growing period of 1909, the distance between the two points of observation being $2\frac{1}{2}$ miles.

TABLE III.—*Comparison of the rainfall, in inches, at the United States Weather Bureau observatory and at the Amarillo Cereal Field Station, Amarillo, Tex., from March 1 to September 30, 1909.*

Station.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Total.
United States Weather Bureau	1.28	0.50	1.08	4.72	3.63	0.87	2.19	14.27
Cereal Field Station	1.08	.27	1.13	5.90	2.19	1.39	1.90	13.86



FIG. 3.—View of a portion of the Amarillo Cereal Field Station after a torrential shower, August 22, 1907, showing the surface run-off which frequently occurs after such showers.

The rains usually are violent and last such a short time that much of the water is unable to get into the soil. For this reason there is a considerable run-off. The beating of the rain frequently makes the condition worse by puddling the surface and partially closing the pores. The run-off after a heavy rain is shown in figure 3.

HUMIDITY.

The atmospheric humidity is, on the average, quite low and plays an important part in crop production.

WIND.

The average hourly wind velocity for the years 1905 to 1910, inclusive, is 12 miles. For this same period there was an average of 13 days each year when the hourly wind velocity was over 40 miles. At times it reaches a much higher velocity. On March 24, 1909, it reached a maximum velocity of 63 miles. Great quantities of soil were carried by this wind; boxes, tin cans, nail kegs, clothing, etc., were scattered over the plats, and even some of the stakes marking the rows in the nursery were blown out of the ground. Great damage is done to crops by such high winds. The crops may be blown down, or they may be covered or cut by the moving particles of soil. For detailed data on wind, see Table V.

EVAPORATION.

Evaporation of moisture from the ground and from the crops themselves is very great, reaching a maximum during periods of drought and high winds. The evaporation from the free water surface of a tank 8 feet in diameter reached a maximum of 0.69 inch in 24 hours in 1909.

During the seven months from March to September, inclusive, in 1909, when the observations recorded in Table IV were made at the farm, the evaporation from a free water surface was more than four times as much as the precipitation for the same period.

TABLE IV.—*Precipitation and evaporation, in inches, at the Amarillo Cereal Field Station, Amarillo, Tex., from Mar. 1 to Sept. 30, 1909.*

Date.	Precipitation.		Evaporation.		Date.	Precipitation.		Evaporation.	
	For dates given.	Total for month.	For dates given.	Total for month.		For dates given.	Total for month.	For dates given.	Total for month.
March:					July:				
1 to 8.....	0	1.08	1.575	4.669	1 to 5.....	0.24	2.19	1.134	10.075
9 to 15.....	.66		(¹)		6 to 12.....	1.14		2.010	
16 to 22.....	0		1.059		13 to 19.....	Trace.		2.484	
23 to 29.....	Trace.		1.842		20 to 26.....	.70		2.558	
30 to 31.....	.42		.193		27 to 31.....	.11		1.889	
April:					August:				
1 to 5.....	0	.27	.978	8.285	1 to 2.....	0	1.39	.712	9.261
6 to 12.....	Trace.		2.514		3 to 9.....	1.81		2.416	
13 to 19.....	Trace.		2.117		10 to 16.....	.06		1.769	
20 to 26.....	.27		1.103		17 to 23.....	.02		2.120	
27 to 30.....	Trace.		1.573		24 to 31.....	0		1.611	
May:					September:				
1 to 3.....	0	1.13	.718	10.042	1 to 5.....	1.88	3.78	1.629	8.411
4 to 10.....	.04		2.514		6 to 12.....	1.88		1.716	
11 to 17.....	0		3.121		13 to 19.....	.02		1.716	
18 to 24.....	.96		1.403		20 to 26.....	0		2.171	
25 to 31.....	.13		2.286		27 to 30.....	0		1.179	
June:					Total.....		15.74		61.039
1 to 7.....	.12	5.90	2.337	10.296					
8 to 14.....	1.98		2.393						
15 to 21.....	.98		2.500						
22 to 28.....	1.94		2.460						
29 to 30.....	.88		.606						

¹ Tank frozen over.

TEMPERATURE.

The highest temperatures have been much lower than might be expected when the altitude is not taken into consideration. The nights are nearly always cool. The average date of the last spring frost is April 18, and that of the first fall frost is October 28. The data on mean temperature, maximum and minimum temperatures, and greatest daily range by months for the years 1905 to 1911, inclusive, are given in Table V, which also presents data on precipitation, the condition of the sky, and the movement of the wind. The highest recorded temperature in the period covered by these records was 105° F., on June 25, 1912, and the lowest, -15° F., on February 13, 1905.

TABLE V.—Climatic data recorded at Amarillo, Tex., for the years 1905 to 1911, inclusive.¹

Month.	Temperature (° F.).						Precipitation (in inches).				Sky (days).				Wind.			
	Mean.	Departure from the normal.	High-est.		Lowest.		Total.	Departure from the normal.	Greatest in 24 hours.	Total snowfall, unmelted.	Rainy.	Clear.	Partly cloudy.	Cloudy.	Prevailing direction.	Movement (miles).	Number of days velocity 40 or more miles.	
			Date.	Read-ing.	Date.	Read-ing.												
Jan..	31.0	- 0.9	30	67	13	- 6	43	1.00	+0.41	0.40	9.9	7	16	8	7	NW.	8,151	0
Feb..	24.0	-11.6	26	62	13	-15	39	1.52	+ .56	.58	18.7	9	8	11	9	N.	7,795	0
Mar..	50.3	+ 4.3	27	78	8	28	41	2.62	+2.23	.80	5	8	15	10	6	SE.	10,859	2
Apr..	52.0	+ 3.0	27	82	15	28	34	4.52	+2.73	1.24	.6	10	19	7	4	SE.	9,512	2
May..	63.1	- 1.0	8	87	4	42	39	6.52	+2.73	3.86	0	10	26	4	1	SE.	10,103	4
June..	73.5	+ 2.0	28	94	21	56	27	2.19	- .88	.88	0	7	25	5	0	SE.	9,559	0
July..	74.0	- 1.0	12	94	9	51	36	3.76	+1.22	1.16	0	9	21	5	5	SE.	5,545	0
Aug..	78.0	+ 3.0	16	98	9	60	34	.63	-2.09	.30	0	6	25	6	0	SE.	8,001	0
Sept..	70.3	+ 2.0	1	96	19	44	34	3.08	+ .70	.94	0	4	20	7	3	S.	8,594	2
Oct..	55.0	- 2.0	16	82	20	29	43	.30	-1.34	.15	0	3	15	3	13	S.	8,124	0
Nov..	46.8	+ .9	27	75	29	18	35	5.09	+4.03	3.02	0	7	16	3	11	SW.	8,821	3
Dec..	34.2	- 2.1	8	60	1	33	38	1.45	+ .46	1.05	9.3	4	16	5	10	NW.	7,738	0

1906.

Jan..	38.8	+ 6.9	29	66	22	14	38	0.41	-0.28	0.23	3	6	13	6	12	SW.	9,499	2
Feb..	38.4	+ 2.8	21	74	5	6	46	.51	- .36	.50	.4	2	17	0	11	SE.	8,148	2
Mar..	39.8	- 5.1	25	74	19	12	54	.64	+ .24	.37	.6	7	18	7	6	NW.	9,092	2
Apr..	55.7	+ .4	23	82	4	31	40	3.23	+1.52	1.33	0	8	16	11	3	SE.	9,516	1
May..	64.4	+ .2	31	90	7	38	38	1.18	-2.00	.57	0	7	22	4	5	SE.	9,112	1
June..	71.3	- 1.1	30	100	4	50	42	2.07	- .99	.84	0	6	22	5	3	SE.	10,389	3
July..	73.6	- 2.4	27	95	4	53	31	2.90	- .44	.72	0	14	18	5	8	SE.	6,588	0
Aug..	73.4	+ .5	22	93	27	53	35	6.76	+4.40	4.02	0	9	19	11	1	SE.	7,921	1
Sept..	69.0	+ 1.6	10	88	30	45	27	1.96	- .61	.94	0	8	21	8	1	SE.	7,659	0
Oct..	53.4	+ 2.8	3	87	23	23	37	2.49	+ .83	.55	9	7	18	6	7	SE.	9,032	0
Nov..	41.1	- 2.8	8	75	20	4	39	2.58	+1.85	1.39	14.8	9	11	11	8	SE.	5,345	0
Dec..	46.0	+ 9.7	3	74	16	25	37	.19	- .80	.19	T.	1	19	8	4	S.	4,097	0

1907.

Jan..	52.4	+10.5	5	74	25	15	46	1.11	+0.42	0.85	0.9	9	15	12	4	S.	9,467	0
Feb..	44.2	+ 8.6	8	74	3	7	42	.24	- .63	.24	.6	1	21	4	3	S.	7,789	1
Mar..	56.8	+11.8	19	96	1	20	46	.02	- .18	.02	0	1	25	4	2	S.	10,039	2
Apr..	52.6	- 2.0	10	90	30	23	55	1.25	- .46	.52	8.3	7	18	8	4	S.	10,313	2
May..	59.0	- 5.3	17	90	4	26	40	.99	-2.19	.34	0	9	20	8	3	NW.	10,260	1
June..	71.6	- .4	29	104	1	44	44	1.97	-1.02	1.36	0	5	21	7	2	S.	9,585	1
July..	76.0	- 1.1	24	99	1	55	36	1.49	-1.68	.73	0	7	21	9	1	S.	9,606	2
Aug..	76.3	+ 1.7	15	97	31	58	35	6.20	+3.39	2.38	0	10	16	11	4	S.	9,019	1
Sept..	70.8	+ 3.1	7	91	28	42	38	.91	-1.45	.68	0	3	17	13	0	S.	8,503	1
Oct..	57.6	+ 1.5	2	86	8	35	57	1.79	+ .80	.65	0	10	10	12	9	S.	8,196	1
Nov..	43.3	- .5	6	74	12	18	38	.66	- .50	.62	4	5	14	9	7	S.	6,725	0
Dec..	38.3	+ 2.0	1	71	18	12	37	1.46	+ .63	1.46	1.4	2	15	11	5	S.	9,773	0

¹ Data furnished by the observer of the U. S. Weather Bureau, Amarillo, Tex.

TABLE V.—Climatic data recorded at Amarillo, Tex., for the years 1905 to 1911, inclusive—Continued.

1908.

Month.	Temperature (° F).							Precipitation (in inches).				Sky (days).				Wind.		
	Mean.	Departure from the normal.	High-est.		Lowest.		Greatest daily range.	Total.	Departure from the normal.	Greatest in 24 hours.	Total snowfall, unmelted.	Rainy.	Clear.	Partly cloudy.	Cloudy.	Prevailing di- rection.	M o v e m e n t (miles).	Number of days velocity 40 or more miles
			Date.	Read- ing.	Date.	Read- ing.												
Jan..	38.8	+ 4.9	9	70	16	7	44	0.26	- 0.35	0.22	0.4	3	18	10	3	S.	10,222	2
Feb..	40.4	+ 3.2	28	77	1	4	43	.72	- .20	.60	6	5	17	10	2	N.W.	9,318	4
Mar..	52.2	+ 7.2	17	86	9	20	48	T.	- .65	T.	0	23	6	2	S.	9,363	2	
Apr..	55.7	+ 1.1	14	80	2	29	38	1.90	+ .18	1.03	0	5	20	9	1	S.	9,093	2
May..	63.5	- .8	19	91	7	34	43	3.55	- .12	2.73	0	5	28	1	2	SW.	11,050	1
June.	73.3	+ 1.3	21	96	2	52	36	1.73	-1.26	.76	0	5	27	3	0	S.	11,011	2
July.	72.8	- 3.3	11	96	7	55	31	5.40	+2.23	1.95	0	11	16	13	2	S.	8,460	0
Aug..	74.5	- .1	10	97	8	58	33	2.75	- .60	.82	0	6	22	9	0	S.	7,891	0
Sept.	67.6	- .1	6	97	28	36	35	1.83	- .53	.74	0	7	22	7	1	S.	7,259	0
Oct..	56.7	+ .6	15	86	27	28	43	.40	-1.31	.15	1	3	27	4	0	S.	9,812	2
Nov..	45.3	+ 1.5	17	78	14	11	46	.51	- .65	.35	1.3	5	24	2	4	N.W.	7,067	1
Dec..	41.2	+ 4.8	16	72	19	18	41	0	- .83	0	0	25	4	2	S.	8,337	0	

1909.

Jan..	41.0	+ 7.1	8	80	12	3	63	0.70	-0.53	0.06	0.6	2	26	4	1	S.	10,167	2
Feb..	41.6	+ 4.4	12	72	14	3	55	.28	- .60	.24	T.	3	22	6	0	S.	10,264	4
Mar..	44.9	- .1	22	80	12	14	45	1.28	+ .63	.57	12.5	5	21	8	2	NW.	9,545	2
Apr..	54.0	- 1.6	17	89	1	26	45	.50	-1.26	.24	1.6	5	24	5	1	S.	10,794	4
May..	62.5	- 1.8	28	93	1	27	45	1.08	-2.59	.85	0	8	21	9	1	S.	9,663	4
June.	73.5	+ 1.5	6	99	3	52	37	4.72	+1.73	1.08	0	14	13	15	2	S.	9,003	2
July.	77.9	+ 1.8	11	96	1	62	30	3.63	+ .46	1.18	0	8	15	16	0	S.	8,270	0
Aug..	78.0	+ 3.4	17	102	25	57	35	.87	-1.94	.34	0	6	12	17	2	S.	7,599	0
Sept.	69.4	+ 1.7	2	95	23	45	40	2.19	- .17	1.49	0	4	18	11	1	S.	7,906	0
Oct..	57.9	+ 1.8	16	88	12	29	44	1.18	- .53	1.13	0	4	20	7	4	S.	9,619	2
Nov..	50.4	+ 6.6	6	85	16	26	45	3.25	+2.09	1.55	6.2	6	16	7	7	S.	8,456	0
Dec..	31.0	- 5.4	31	75	19	3	40	.54	- .29	.41	5.3	4	15	10	6	N.	7,878	0

1910.

Jan..	39.6	+ 5.7	1	76	5	9	40	0.05	-0.55	0.03	0.3	3	10	15	6	SW.	8,483	0
Feb..	35.6	- 1.6	14	76	17	- 4	44	.17	- .71	.17	1.7	1	15	9	4	N.	8,981	0
Mar..	56.5	+11.0	25	87	10	31	48	.34	- .31	.21	0	3	24	7	0	S.	9,183	4
Apr..	58.5	+ 3.9	29	94	5	30	43	.59	-1.13	.26	1.1	4	22	5	3	NW.	9,578	1
May..	61.6	- 2.7	10	95	3	38	39	2.99	- .68	.79	0	11	10	15	6	N.	9,294	0
June.	75.9	+ 3.9	2	103	11	50	40	.66	-2.33	.31	0	7	15	15	0	S.	9,629	0
July.	79.5	+ 3.4	8	100	1	58	37	3.57	+ .40	2.07	0	8	15	16	0	S.	8,330	1
Aug..	76.3	+ 1.7	28	99	26	49	36	2.19	- .62	.72	0	10	18	13	0	S.	7,691	1
Sept.	73.8	+ 6.1	11	101	27	46	44	.05	-2.31	.05	0	1	16	14	0	S.	8,694	0
Oct..	60.4	+ 4.3	4	94	28	28	45	.26	-1.45	.24	1.6	3	23	7	1	S.	8,306	0
Nov..	49.0	+ 5.0	12	82	30	24	39	.28	- .88	.27	2.7	2	23	6	1	S.	7,642	0
Dec..	39.8	+ 3.4	9	73	30	16	42	T.	- .83	T.	T.	0	15	12	4	S.	8,155	0

1911.

Jan..	45.6	+11.7	31	82	3	- 6	44	0.13	-0.47	0.07	0.5	3	14	16	1	SW.	9,309	..
Feb..	38.6	+ 1.4	1	77	22	7	37	2.88	+2.00	1.84	7.3	7	18	5	5	SE.	8,370	..
Mar..	51.4	+ 6.4	9	83	1	21	42	.50	- .15	.50	0	2	25	6	0	S.	9,272	..
Apr..	56.8	+ 2.2	22	87	7	35	42	2.76	+1.04	2.68	0	6	16	11	3	S.	9,732	..
May..	65.6	+ 1.3	9	92	1	36	39	5.88	+2.21	2.90	0	8	15	14	2	SE.	11,140	..
June.	77.0	+ 5.0	25	105	4	59	35	.20	-2.79	.11	0	3	21	9	0	SE.	8,544	..
July.	75.4	- .7	5	96	25	54	29	3.85	+ .68	1.15	0	18	7	19	5	SE.	7,160	..
Aug..	75.8	+ 1.2	6	102	28	54	38	2.97	+ .16	2.63	0	5	18	11	2	SE.	7,711	..
Sept.	75.2	+ 7.5	5	95	19	54	36	.83	-1.53	.41	0	4	16	13	1	S.	7,076	..
Oct..	57.1	+ 1.0	1	91	28	26	45	.84	- .87	.34	3.1	6	18	8	5	S.	8,363	..
Nov..	41.6	- 2.2	16	75	29	5	57	.94	- .22	.41	8.2	5	20	7	3	SW.	9,651	..
Dec..	30.1	- 6.3	4	63	31	0	33	.95	+ .12	.83	9	8	18	8	5	SW.	6,792	..

EXPERIMENTAL WORK AT CHANNING.

COOPERATIVE ARRANGEMENTS.

In the fall of 1903 arrangements were made with the Capitol Freehold Land & Investment Co., owners of large tracts in the Panhandle region of Texas, to conduct some cooperative experiments in cereal production on their large headquarters ranch, the XIT ranch at Channing. Under the agreement they were to provide the land and labor, and the Office of Cereal Investigations was to supply the seed and scientific assistance required. The experimental work was placed in charge of the junior writer. The land provided was 50 acres near the town of Channing, lying between the Fort Worth & Denver City Railway and the main road to the ranch from the town.

PHYSICAL DATA FOR CHANNING.

The elevation of Channing is 3,900 feet, about 300 feet higher than Amarillo, which is about 50 miles distant. The deep valley or canyon of the Canadian River is between the two towns. The soil is lighter in texture than that around Amarillo and is classed as a sandy loam or sandy clay loam. The soil used in the experiments was rather thin, due probably to more than average erosion, as some small canyons tributary to the Canadian River head less than half a mile to the eastward.

The climatic conditions are very similar to those for Amarillo, though the rainfall probably averages a little lower and the effect of high winds is greater on the more sandy soils.

The rainfall data for the three years during which experiments were conducted are shown in Table VI.

TABLE VI.—*Monthly and annual precipitation, in inches, at Channing, Tex., during 1904, 1905, and 1906.*

Month.	1904	1905	1906	Month.	1904	1905	1906
January.....	18.90	0.70	0.20	August.....	2.56	2.03	2.47
February.....		1.20	.56	September.....	4.05	5.65	2.57
March.....		2.48	.18	October.....	2.42	.45	1.10
April.....		5.52	3.26	November.....	.25	4.86	1.55
May.....		2.27	1.54	December.....	.60	.60	0
June.....		1.35	0	Annual.....	18.78	29.34	15.24
July.....		2.23	1.81				

¹ Reliable U. S. Weather Bureau instruments were in use after July, 1904. The rainfall for 1904 previous to their installation was carefully measured, but the record was not kept by months.

CROPPING CONDITIONS WHEN THE EXPERIMENTS WERE BEGUN.

The experimental work was greatly hindered at the beginning by the climate and cropping conditions at that time. The land had been broken from the sod in the spring of 1903, disk harrowed, and planted to milo with a lister. The growing crop received a drag harrowing and one cultivation. This crop was cut with a corn binder

and removed from the land. The experimental work was commenced October 20, 1903. As it was late and exceedingly dry, the land intended for fall seeding was not plowed but was double-disked instead and sown with a drill. A light rain in October moistened the surface soil and part of the seed germinated. As sufficient rain to cause germination and subsequent growth did not fall until April 28, 1904, the fall-sown small grains were a total failure, with the exception of a few individual plants.

All land intended for planting in the spring of 1904 was plowed during the previous dry autumn. As no rain fell until the latter part of April, the moisture supply was deficient, and germination of the spring grain took place irregularly throughout the month of May. With good summer preparation in 1903 the results would probably have been very different.

The preparation for the crop of 1905 was started in July, 1904. Later in that year a marked increase in the rainfall began and lasted for most of the year following. All plowing and tillage after the first year were thoroughly and promptly done, the desire being to put the soil in as good condition as possible, except in the special tillage operations.

GENERAL PLAN OF PRELIMINARY EXPERIMENTS.

When the experimental work at Channing was commenced, the region was almost wholly used for cattle grazing. A few settlers were coming in and attempting to farm. Some of the ranchers also cultivated small fields. The crops which it was known would grow at all were limited, and there was little information as to suitable varieties of those supposed to be adapted to the locality. Therefore, at the start the work was of necessity very crude and elementary.

Some varieties of grain which were believed to be suitable for growing in the Panhandle region were planted in large plats, a few being as large as 4 or 5 acres each. It was hoped that some of these larger plantings would be successful, and thus adapted seed would be available for use and for distribution to farmers.

Many varieties of grains from all parts of the world were planted in small quantities. Most of these plantings were made in the cereal nursery, using only 1 ounce of seed of each variety. The seed of commercial varieties ordinarily obtainable is often a mixture of various strains, and much improvement usually can be effected by separating these strains, which are then grown and compared as if they were separate varieties. This kind of work seemed to be so necessary in many cases that where a commercial variety which was grown in a large plat proved to be much mixed it was sown in the nursery the next year and carefully purified before being again grown in the field.

In order to find varieties which might prove to be adapted to the conditions, 457 varieties of small grain were grown in a total of 912 tests during the three years in which experiments were conducted at Channing. Most of these varieties proved unfit and were discarded during the first two years. Only 31 of the most promising varieties were used in a total of 44 tests in 1906. All the varieties which were not extremely promising were omitted from the Channing tests that year, but were used in the work which was then begun at Amarillo, as were promising varieties of which only small quantities of seed were available. Yields are not reported in the Channing tests for plats smaller than one-tenth of an acre.

VARIETAL EXPERIMENTS WITH WINTER GRAINS.

In the autumn of 1903 winter grains were seeded on an extensive scale at Channing. All varieties which were sown in field plats were failures. In the nursery some few spots were sufficiently moist to induce germination, but as there was no rain during the winter only a very few plants survived. The season of 1904 permitted quite good preparation for the planting of fall-sown small grains, and fairly good crops were obtained. The season of 1905-6 furnished the most favorable conditions which had yet occurred for preparation of the soil, and very good crops were again obtained, although the spring rainfall was deficient.

The tests of winter small grains furnished very dependable data on which to base the cultural and varietal experiments which were begun in 1906 on farm No. 1 at Amarillo, and also provided seed for use there. The results of these tests are shown in Table VII.

TABLE VII.—*Annual and average yields of varieties of winter small grains at Channing, Tex., for the years 1905 and 1906.*

C. I. No. ¹	S. P. I. No. ²	Name.	Original source.	Yield per acre (bushels).		
				1905	1906	Average.
		WINTER WHEAT.				
2398	9872	Galgalos	Russia	18.16	23.40	20.78
2208	9125	Kharkof	do.	16.71	24.50	20.60
1596	7582	Freres	Algeria	18.00	20.60	19.30
2239	9358	Beloglina	do.	12.93	23.50	18.21
2900		Mixed wheat	Local	20.00	16.00	18.00
2219	9129	Padi	Russia	13.47	10.93	12.20
2246	10364	Kubanka ³	do.	9.58	7.00	8.29
2100	13855	Black Don ³	do.		10.10	
2227	9131	Chul ⁴	do.	6.85		
		WINTER EMMER.				
2337	11650	Black Winter	France	51.20	31.20	41.20
		WINTER BARLEY.				
257	11193	Tennessee Winter	Virginia	11.40	32.50	21.95
		WINTER RYE.				
34	10367	Ivanov	Russia	19.10	16.50	17.80
114			Kansas	14.79	17.26	15.72
40	10366	Abruzzes	Italy	7.23		

¹ Serial number of the Office of Cereal Investigations.

² Serial number of the Office of Foreign Seed and Plant Introduction.

³ Spring durum wheat planted in the fall.

⁴ Spring common wheat planted in the fall.

Winter wheat.—In the subsequent varietal tests at Amarillo all of the winter wheat varieties in Table VII were discarded except Kharkof and Beloglina, either because of lack of hardiness (in some



FIG. 4.—Field of fall-sown Fretes wheat (C. I. No. 1596) at Channing, Tex., in 1906.

years they have entirely winterkilled), or because of their low yield. The two varieties which have been retained, Kharkof (C. I. No. 2208) and Beloglina (C. I. No. 2239), are both hard red winter wheats from

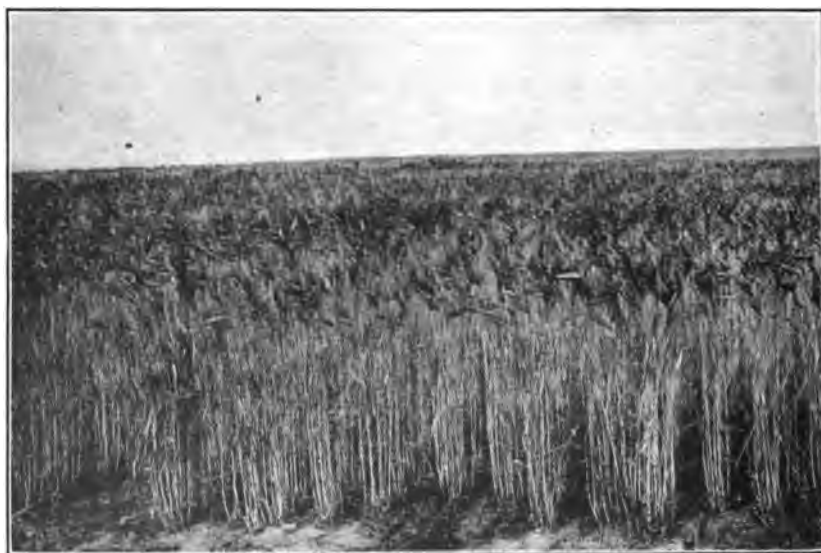


FIG. 5.—Field of Black Winter emmer (C. I. No. 2337) at Channing, Tex., in 1905.

Russia. The three spring wheats which were tested for adaptability as winter sorts were conspicuously poor yielders in this test. A field of Fretes wheat at Channing in 1906 is shown in figure 4.

Winter emmer.—Emmer is a cereal closely related to wheat, but which retains its chaff. The variety here reported upon is probably of Russian origin. It weighs about 30 pounds per bushel and is quite hardy. It is of value only as a crop for feeding to live stock. A plat of this grain at Channing in 1905 is shown in figure 5.

Winter barley.—All varieties of barley which were tested at Channing produced very unsatisfactory yields. The Tennessee Winter variety was the only one tested in field plats.

Winter rye.—The two varieties which were tested each year did not yield as well as was expected. Further testing at Amarillo has reversed the position of these varieties in regard to yield.

VARIETAL EXPERIMENTS WITH SPRING SMALL GRAINS.

In the autumn of 1903 plowing was done for the spring small-grain tests of 1904. This land was worked in very dry weather and spring seeding was done when there was no hope for immediate germination. Rains came so late that the tests were not at all typical of what can be secured under favorable conditions. The tests in 1905 and 1906 were made on well-tilled land. Many nursery tests with these grains were conducted in 1904 and 1905. These tests were continued at Amarillo, and many good strains from the nursery are now in the field tests. The yields from the spring small grains at Channing are given in Table VIII.

Durum spring wheat.—Owing to the necessity of purifying the varieties used in 1904 and 1905, the field tests were greatly restricted until pure strains of the best sorts could be selected and increased. Thus most of the tests reported in Table VIII are on the first year's crop only and the yields recorded are in no way conclusive.

Common spring wheat.—Three of the varieties reported in Table VIII have been continued at Amarillo and very valuable data obtained. Their yields are very close to those of the durum. It will be noted that these common wheats (with the exception of the Sonora, which was of little value) came from countries where durum wheats are commonly grown.

Spring oats.—The Burt oat, which has made the best yields (Table VIII), is an extremely early brown variety, prominent throughout the South. It resembles Red Rustproof in some characteristics, but it is earlier. The Sixty-Day is an early yellowish white variety, slightly later than the Burt.

Spring barley.—The data obtained from the tests of spring barley are shown in Table VIII. This crop has given uniformly poor yields at both Channing and Amarillo.

TABLE VIII.—*Annual and average yields of varieties of spring small grains at Channing, Tex., for the years 1904, 1905, and 1906.*

C. I. No.	S. P. I. No.	Name.	Original source.	Yield per acre (bushels).					
				1904	1905	1906	Average for—		
							3 years.	1904 and 1905.	1905 and 1906.
DURUM WHEAT.									
2088	7794	Kahla.....	Algeria.....	1.50	.....	.....	.....	.....	.....
2099	7792	Mahmoudi.....	do.....	2.00	.....	.....	.....	.....	.....
2222	8523	Velvet Don.....	Russia.....	.50	.....	.....	.....	.....	.....
2247	9479	do.....	do.....	.50	.....	.....	.....	.....	.....
2091	7428	Albacete.....	Spain.....	3.11	6.81	13.64	7.85	4.96	10.22
2934	.....	.....	Algeria.....	3.75	9.50	.....	.....	6.62	.....
1593	7578	Marouani.....	do.....	1.66	8.50	.....	.....	5.08	.....
1597	7579	Medeah.....	do.....	.....	9.41	.....	.....	.....	.....
2085	7585	Black Poulard.....	do.....	.....	7.00	.....	.....	.....	.....
2228	9130	Saragolla.....	Italy.....	8.83	.....	.....	.....	.....	.....
2235	9324	Marouani.....	Algeria.....	10.83	.....	.....	.....	.....	.....
2882	15788	Kubanka.....	Russia.....	9.60	.....	.....	.....	.....	.....
2941	.....	.....	.....	8.26	14.21	.....	.....	.....	11.23
2246	9478	Kubanka.....	Russia.....	9.63	14.54	.....	.....	.....	12.08
2246	10364	do.....	do.....	9.00	15.00	.....	.....	.....	12.00
COMMON SPRING WHEAT.									
1596	7582	Fretes.....	Algeria.....	.83	4.85	.....	.....	2.84	.....
2398	9872	Galgalos.....	Russia.....	1.66	6.87	13.41	7.31	4.26	10.14
2227	9130	Chul.....	do.....	.....	7.84	15.33	.....	.....	11.58
2227	15802	do.....	do.....	.....	8.50	.....	.....	.....	.....
2940	.....	Sonora.....	Colorado.....	.....	4.58	.....	.....	.....	.....
SPRING OATS.									
293	11145	Burt.....	Virginia.....	1.56	25.78	26.40	17.91	13.67	26.09
458	.....	Red Rustproof.....	.....	4.67	19.55	24.25	16.15	12.11	21.90
165	5938	Sixty-Day.....	Russia.....	4.53	18.60	18.00	13.71	11.56	18.30
296	12133	Red Algerian.....	Algeria.....	.....	11.43	.....	.....	.....	.....
213	10330	Swedish Select.....	Russia.....	1.87	8.35	.....	.....	5.11	.....
254	8650	North Finnish Black.....	Finland.....	1.34	5.62	.....	.....	3.48	.....
451	.....	Red Rustproof.....	Kansas.....	.....	.....	17.64	.....	.....	.....
SPRING BARLEY.									
261	9877	Mariout.....	Egypt.....	.....	12.70	.....	.....	.....	.....
195	7969	White Smyrna.....	Asia Minor.....	.....	12.50	.....	.....	.....	.....
354	11192	Manchuria.....	Ontario.....	.....	8.49	.....	.....	.....	.....
226	9133	Hanna.....	Austria.....	1.50	5.67	.....	.....	3.58	.....
507	17525	Boehme Hooded.....	Idaho.....	.....	.....	8.45	.....	.....	.....

RATE-OF-SEEDING TESTS WITH SMALL GRAINS.

In undertaking varietal experiments in a new region it is frequently a matter of much concern to know just how much seed to use in planting. The Channing experiments were based on the opinions of such ranchmen and farmers as could give information. Because of lack of seed of adapted varieties and of land for extensive tests, very few rate-of-seeding tests were conducted. Table IX shows the results obtained in these tests, which were too few and of too short duration to be conclusive.

TABLE IX.—*Annual and average yields obtained in rate-of-seeding tests with wheat and emmer at Channing, Tex., in 1905 and 1906.*

C. I. No.	S. P. I. No.	Name.	Rate sown.	Yield per acre (bushels).		
				1905	1906	Average.
2308	9872	WINTER WHEAT.	Pecks.			
		Galgalos.....	3		23.40	
2337	11650		4		19.29	
		WINTER EMMER.				
		Black Winter.....	6		31.20	
			7	51.20		
2246	10364		8	43.00	31.00	37.00
		SPRING WHEAT.				
			3	9.25		
			4	10.83	13.91	12.37
		Kubanka (durum).....	5	8.33		
			6	9.00	15.00	12.00
2227	9131		17	9.50		
			18	8.50	15.38	11.94
			4		15.33	
		Chul (common).....	5		14.86	
		12		13.23		

¹ These plats showed a crowded stand and a poorer quality of grain both years.

DATE-OF-SEEDING TESTS WITH WINTER WHEAT AND BARLEY.

Table X shows the results obtained in the date-of-seeding tests conducted with winter wheat and winter barley. They are, of course, quite too meager to be conclusive. An interesting feature of the date-of-seeding test of winter barley was the apparent effect of the date of planting on the presence of smut in the plats. The plat sown on September 21 contained 20 per cent of smut and that sown on October 7 contained 22.5 per cent, while no smut was found in the plat sown on November 28. The percentage of smutted heads was determined by actual counts of 1,000 heads in several parts of each plat.

TABLE X.—*Yields obtained in date-of-seeding tests with winter wheat and winter barley at Channing, Tex., in 1906.*

Variety.	Date planted.	Date ripe.	Yield per acre (bushels).
Winter wheat:			
Padi.....	Sept. 12		10.18
	Sept. 21		14.45
Winter barley:			
Tennessee Winter.....	Sept. 21	June 6	21.61
	Oct. 7	June 12	32.50
	Nov. 28	June 21	21.28

FALLOWING AND CONTINUOUS CROPPING AS PREPARATION FOR WINTER WHEAT.

The results of preliminary experiments to compare the effects of alternate fallowing and of continuous cropping to wheat in the production of winter wheat are given in Table XI.

TABLE XI.—*Yields of winter wheat at Channing, Tex., in 1905 and 1906, from plats fallowed the previous year and plats continuously cropped.*

Treatment.	Year, variety, and yield (bushels).				
	1905		1906	Total for 2 years.	Average.
	Padl.	Beloglina.	Kharkof.		
Fallowed the previous year.....	16.73	25.89	30.00	30.00	15.00
Continuously cropped.....	13.47	12.93	22.50	35.43	17.71
Gain from fallowing.....	3.26	12.96	7.50	5.43	2.71
Gain by continuous cropping.....					

The yields of 1905 are inconclusive, since there are no data of 1904 to compare with them. In 1906, however, the continuously cropped plat is the one occupied by Beloglina in 1905, and, its performance being known, comparison can be made, as shown in Table XI.

The tillage required in fallowing was almost as expensive as that in raising a crop; therefore definite conclusions would have to be based on the comparative expense of seed, planting, harvesting, etc., of two crops instead of only one.

COMPARISON OF HOME-GROWN AND KANSAS-GROWN SEED OF SPRING OATS.

In 1906 Burt oats (C. I. No. 293, S. P. I. No. 11145), grown originally at McPherson, Kans., in 1903, and continuously at Channing since 1904, was compared with Burt oats (S. P. I. No. 15856) grown continuously at McPherson since 1903, from the same original seed. The home-grown seed yielded 26.4 bushels and the Kansas seed 13 bushels, a gain of 13.4 bushels in favor of home-grown seed in this test during a single season.

SUMMARY OF YIELDS OF SMALL GRAINS.

A summary of the average yields of the different classes of small grains at Channing during 1905 and 1906 is given in Table XII.

TABLE XII.—*Average yields of small grains obtained at Channing, Tex., in 1905 and 1906.*

Kind of grain.	Average yield per acre.		Kind of grain.	Average yield per acre.	
	Bushels.	Pounds.		Bushels.	Pounds.
White winter wheat (Galgalos)	20.78	1,247	Winter emmer.....	41.20	1,030
Hard red winter wheat.....	20.60	1,236	Winter barley.....	21.95	1,054
Durum spring wheat.....	12.08	725	Winter rye.....	17.80	1,001
Common spring wheat.....	11.58	705	Spring oats.....	26.09	835

The Galgalos variety of white winter wheat reported in Table XII was afterwards discarded at Amarillo as a winter variety. It is still grown there as a spring wheat.

VARIETAL EXPERIMENTS WITH CORN.

In general, the corn crops at Channing were very poor. The cool nights common to these elevated plains are not favorable to the growth of corn, nor does it stand well the severe droughts, which are not uncommon. The largest yield obtained was 35 bushels per acre. Counting each year's tests as separate, 105 varieties were grown during the three years and 131 tests were made.¹ Some of these trials were on a very small scale and of no importance. The results of field tests of varieties are shown in Table XIII. Unless otherwise noted, the yields recorded each year are the average of two plats grown in different portions of the field.

TABLE XIII.—*Annual and average yields of varieties of corn at Channing, Tex., in 1904 and 1905.*

Name of variety.	Source of seed.	Yield per acre (bushels).		
		1904	1905	Average.
Channing Red.....	Local.....	9.25	32.43	20.84
Marlboro Prolific.....	South Carolina.....	7.75	24.11	15.93
Cocke's Prolific.....	Tennessee.....	5.00	19.50	12.25
Funk's Ninety-Day.....	Illinois.....	6.75	13.25	10.00
Leaming Yellow.....	Ohio.....	6.50	5.82	6.16
Pride of the North.....	Illinois.....	3.25		
Boone County White.....	District of Columbia.....	3.00		
McMackin's Gourdseed.....	District of Columbia.....	2.50		
U. S. P. B. No. 74.....	District of Columbia.....	2.17		
U. S. P. B. No. 77.....	Ohio.....	4.17		
Dakota Sunshine.....	North Dakota.....		.41	
Do.....	do.....		17.62	
Minnesota No. 13.....	Minnesota.....		.50	
Do.....	do.....		110.39	
Sterling Yellow Dent.....	do.....		2.33	
Do.....	do.....		18.24	
Ninety-Day Yellow Flint.....	Connecticut.....		.50	
Do.....	do.....		13.62	
Early Tuscarora.....	South Dakota.....		.70	
Do.....	do.....		15.87	
Leidigh's Yellow.....	Kansas.....		28.97	
Leidigh's White.....	do.....		24.40	
Leidigh's Leaming.....	do.....		19.59	
Hildreth's Yellow.....	do.....		24.21	
Mexican June.....	Alabama.....	Failed.		
Throckmorton's June.....	Local.....		22.00	
Alexander's White.....	do.....		23.70	
C-1. No. 92.....	Illinois.....		13.11	

¹ Yield of one plat planted on May 30.

² Yield of one plat only.

The season of 1904 was very unfavorable for corn, opening with no moisture and continuing dry throughout. The varieties were all planted on April 12. The Channing Red, a local variety, and Marlboro Prolific kept in much better condition than the other sorts during the

¹ Acknowledgment is made to Mr. C. P. Hartley, of the Office of Corn Investigations, for 24 of the 105 lots of seed tested and for assistance in planning the corn tests.

growing period. The Mexican June corn also looked well, but did not mature any seed. The plantings of the Mexican June corn in later years were from home-grown or shorter season strains.

The season of 1905 was very moist, and the corn crop did well. The regular plantings were made on April 21. The varieties planted May 30 were early-maturing ones which it was thought might be suitable for late planting, except the June corn, which observation had shown to be a failure unless planted late. The crop of 1906, when five varieties were tested, was a failure, owing to the continued drought. Only the Channing Red, a local variety, produced grain. The yield of this variety was 6 bushels to the acre. It will be observed from the tests here reported that early northern types are not adapted and that long-season, late-maturing sorts have proved best.

When corn is compared with the grain sorghums, it will be seen how poor the corn yields really are. The 3-year average yield of the best variety of corn was 15.89 bushels to the acre, while the average yield of milo for the same period was 42 bushels. The available data on the comparative feeding value of corn and milo are limited. The lowest figure would make a bushel of milo 20 per cent less valuable than a bushel of corn, but ordinarily it is considered only 10 per cent less valuable.

EXPERIMENTS WITH GRAIN SORGHUMS.

The grain sorghums are the standard on which all comparisons of cropping results in the Panhandle must be based, as they grow during the summer and fall when the most abundant rainfall is to be expected, and are adapted to use under the relatively high temperatures which occur during these months. In 1904, 4 varieties were tested; in 1905, 103 varieties were used in 125 tests; and in 1906, 24 varieties were planted. In 1906 the grain-sorghum nursery was planted at Amarillo, so only field plats were under test at Channing. These were cared for almost wholly by Mr. J. J. Edgerton, superintendent of the XIT farm. In 1905 the plantings of Red and Black-hull kafir were not comparable with those of milo, therefore complete 3-year averages are not obtainable. The 2-year averages may be regarded as reliable, as the results of the nursery tests of these varieties in 1905 are similar to the field-plat averages. The data obtained are given in Table XIV. Figure 6 shows a field of Blackhull kafir on the XIT ranch in 1906.

TABLE XIV.—*Annual and average yields of grain-sorghum varieties obtained at Channing, Tex., in 1904, 1905, and 1906.*

Variety.	1904			1905			1906			Average of 1904 and 1906.		
	Total crop.	Grain.		Total crop.	Grain.		Total crop.	Grain.		Total crop.	Grain.	
	Lbs.	Bus.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	Bus.	Lbs.
Milo.....	4,800	40	2,240	5,603	40	2,240	5,140	46	2,570	4,970	43	2,405
Red kafir.....	6,520	35	1,960	.....	.....	.....	7,884	47	2,652	7,202	41	2,306
Blackhull kafir.....	5,875	31	1,736	.....	.....	.....	6,874	35	1,994	6,374	33	1,865
"Jerusalem corn".....	4,100	22	1,232	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dagdi jowar.....	.....	.....	.....	8,408	40	2,240	.....	.....	.....	.....	.....	.....
Edra durra.....	.....	.....	.....	4,488	.....	.....	.....	.....	.....	.....	.....	.....
Milo-sumac cross.....	.....	.....	.....	.....	.....	.....	11,480	.....	.....	.....	.....	.....
Milo-kafir cross.....	.....	.....	.....	.....	.....	.....	7,022	.....	.....	.....	.....	.....
Shallu.....	.....	.....	.....	.....	.....	.....	3,192	19.5	1,092	.....	.....	.....



FIG. 6.—Field of Blackhull kafir on the XIT ranch at Channing, Tex., in 1906.

From 4 to 8 pounds of seed per acre were used in these tests, and a little thinning was done to obtain a uniform stand. It will be noted that in the tabulated data the yields of the grain are given in pounds to the acre, as well as in bushels. The different varieties of grain sorghums in the area under consideration vary in test weight per measured bushel. The thrashing machinery cuts or cracks a considerable portion of the grain and removes the glumes to a greater or less extent. As the cracking and hulling varies with different machines, varieties, and conditions of moisture, results given in bushels

of a certain weight are somewhat misleading. The grain is treated commercially like corn, oats, mill feeds, etc., in that region, being handled either in bulk or sacked and sold in units of 100 pounds. Prices for these grains are almost invariably quoted by the hundred-weight, rarely by the bushel. The value is therefore based on the total weight irrespective of the weight per bushel.

Milo, which was the only variety of grain sorghum grown in field plats all three years, produced an average of 42 bushels, or 2,350 pounds of grain for the period. It also produced a higher average yield for the two years, 1904 and 1906, than either Red or Blackhull kafir.

EXPERIMENTS WITH MILO.

In 1903 the junior writer devoted considerable time to travel, observing crops and cropping conditions. The good qualities of milo as a field crop were very evident in the Panhandle, and comprehensive tests were planned. Fairly uniform strains were found and many field tests were made in 1905, while other varieties were being purified in the nursery. Table XV shows the results of the rate-of-planting tests with this crop. The lack of uniformity in the results of various years is due largely to differences in quality of seed and the seasonal influences on germination. It should be added that the spring condition of the soil in both 1905 and 1906 was very good and that later tests at Amarillo have seemed to justify thinner seeding than here shown, probably because of drier seasons.

TABLE XV.—*Yields of milo obtained from thick, medium, and thin planting at Channing, Tex., in 1904, 1905, and 1906.*

Relative stand.	Distance between plants in 42-inch rows.	Yield per acre.		
		Total crop.	Grain.	
	Inches.	Pounds.	Pounds.	Bushels.
Crop of 1904:				
Thick.....	4	4,800	2,240	40
Crop of 1905:				
Thick.....	4.25	5,603	2,240	40
Do.....	5	4,331	1,792	32
Medium.....	12	4,399	1,512	27
Thin.....	15	5,320	1,904	34
Do.....	15	4,501	1,736	31
Do.....	17	4,875	1,680	30
Crop of 1906:				
Thick.....	6.9	4,551	1,567	28
Do.....	7.3	5,278	1,759	31
Do.....	8.7	5,278	1,602	28
Medium.....	10.4	4,906	1,398	25

Miscellaneous tests with milo are shown in Table XVI. These include a date-of-planting test and data on the first tests of selected seed from erect-headed plants, also a test of noncultivated compared with cultivated milo.

TABLE XVI.—*Yields of fodder and grain obtained in miscellaneous tests of milo at Channing, Tex., in 1905.*

Description of test.	Yield per acre.		
	Total crop.	Grain.	
	Pounds.	Bushels.	Pounds.
Planted thick, Apr. 26.....	4,402	31	1,736
Planted thick, May 17.....	5,140	46	2,570
Selection from pendent-headed plants, thick stand.....	4,880	35	1,960
Selection from erect-headed plants, thick stand.....	3,540	26	1,456
Planted late with grain drill, 2 pecks per acre.....	4,690	41	2,296
Planted late in rows and cultivated.....	5,371	37	2,072

EXPERIMENTS WITH KAFIR.

Kafir has been grown in the Panhandle to a small extent since its first distribution by the Department. Preliminary observations showed that the kafirs generally were late in maturing and were also badly hybridized with sorghos or sweet sorghums; therefore attention was devoted in 1905 to obtaining pure strains rather than to yield tests. A rate-of-planting test with the selected seed was conducted in 1906, the results of which are given in Table XVII.

TABLE XVII.—*Yields of fodder and grain obtained from different rates of planting Blackhull kafir at Channing, Tex., in 1906.*

Distance between plants in 42-inch row.	Yield per acre.		
	Total crop.	Grain.	
	Pounds.	Bushels.	Pounds.
2.2	6,874	35	1,994
3.2	5,992	33	1,899
4	5,690	29	1,641
5.6	6,549	31	1,733
6	6,686	30	1,719

VARIETAL TESTS OF PROSO, OR RUSSIAN GRAIN MILLET.

Proso is a grain crop which includes certain varieties of the so-called panicle or broom-corn millet (*Panicum miliaceum*). It may have some importance as a catch crop in the Panhandle region. It grows rapidly and can be utilized as a feed for chickens, sheep, or hogs, in addition to the uses which are ordinarily made of the crops of the region. The seed is not readily available locally. Planting is done the latter part of May, using 20 pounds of seed to the acre. The yields obtained at Channing are given in Table XVIII.

TABLE XVIII.—*Yields of proso obtained at Channing, Tex., in 1904 and 1905.*

C. I. No.	S. P. I. No.	Variety.	Yield per acre (bushels).		
			1904	1905	2-year average.
21	9423	Red Orenburg.....	5.53	.....	.....
21	9423	.....do.....	5.58	.....	.....
26	9424	Red Voronezh.....	8.20	.....	.....
27	9425	Black Voronezh.....	10.00	19.63	14.81

No experiments with proso were conducted at Channing in 1906. In 1904 and 1905 a total of 19 varieties were grown in 39 tests.

EXPERIMENTAL WORK AT AMARILLO.

CLIMATIC AND SOIL CONDITIONS.

The city of Amarillo is located in latitude 35° 12' N. and longitude 101° 51' W., at an altitude of 3,676 feet. The climatic conditions, which are fairly representative of the Panhandle region as a whole, have already been fully discussed. As will be noted, nearly all the climatic data presented in this bulletin were obtained from the records of the United States Weather Bureau at Amarillo.

The soil is a chocolate-colored clay. It is locally known as "tight" or "short-grass" land and is covered with a mixed sod of buffalo grass and blue grama, with a small proportion of other grasses. This chocolate-colored soil is from 3 to 5 feet deep, with a reddish clay subsoil. The depth to water is from 200 to 300 feet. Figure 2 (p. 13) gives a general idea of the surface condition of the unbroken land.

THE FIRST FARM.

The farm on which the experimental work was first established at Amarillo consisted of 100 acres of practically level land lying only one-fourth mile distant from the city limits, on the southwest side. The land and permanent equipment were furnished by the Amarillo Chamber of Commerce and held under annual lease renewable at option for a period of five years. In addition to the land, a two-story building was provided for use as an office, laboratory, and seed house combined. Later, a small implement shed was provided. No house, barn, or well was supplied on this farm.

The land was fairly well adapted for experimental purposes, except that it was badly cut by old roads and trails dating from the day of unfenced lands under the range system, as shown in figure 2.

THE PRESENT FARM.

The new farm consists of 120 acres of level, short-grass land lying about 2 miles northeast of the town and about 4 miles distant from the first farm. The northern boundary is a well-traveled public road, while the southern boundary is an oblique line formed by the right of way of the Atchison, Topeka & Santa Fe Railway. A few rods farther south is the Chicago, Rock Island & Gulf Railway, while the tracks of the Fort Worth & Denver City Railway are about three-fourths of a mile distant in the same direction.

This farm and its equipment are provided by the Amarillo Chamber of Commerce, by which organization it is leased to the Department of Agriculture for a term of 15 years with an option by the Department of extending the lease for the further term of 5 years, if desired. The equipment consists of a good dwelling house, barn, seed house and laboratory, well, windmill and tank, and fence. The principal buildings and a portion of the farm are shown in figure 7.

This farm was made available in 1908 and the experimental work thereon was begun with the planting of winter grains in the fall of 1909. Owing to the fact that the farms are less than 4 miles apart and that soil and other environmental conditions are practically identical, the transfer of the experiments from one location to the other does not break their continuity.

SYSTEM OF UNIFORM PLATS.

Both the farms at Amarillo were divided into uniform plats of one-tenth acre each, being 50 by 200 links or 2 by 8 rods in size. Roadways 30 links or 19.8 feet wide at the ends of the plats and alleys 7 links or 4.62 feet wide separate the plats from one another. By using this system, the crop, variety, yield, etc., of each plat for any year are definitely known and error or confusion is less probable. The use of plats of equal size in the tests makes uniform the effect of the surplus feeding area which is available around the edge of the plat, and which certainly varies where plats of different sizes or shapes are used. The surplus feeding area influences comparisons of yield per acre on nonuniform plats even where careful surveying is done. General views of the plats on the two Amarillo farms are shown in figures 8 and 9.

ENLARGED FACILITIES AND COOPERATION.

With the transfer of the work from Channing to Amarillo, which was begun in the fall of 1905 and completed during the summer of 1906, the facilities for conducting the work were greatly enlarged.

The farm at Amarillo contained double the area used in the experiments at Channing. Better machinery was added from time to time, more help was available, and the work as a whole was made more permanent. Up to the time of this transfer the Office of Cereal Investigations had conducted all the experiments. As the work grew, other offices in the Bureau of Plant Industry became interested



FIG. 7.—General view of the buildings on the new farm of the Amarillo Cereal Field Station, Amarillo, Tex.

and it was but a short time until various cooperative experiments were instituted.

Most of the cultivation and rotation experiments which had been started were transferred at this time to the Office of Dry-Land Agriculture, and a large series of very definite experiments was inaugurated. The general plan of the work is to determine the effect of con-



FIG. 8.—View of a portion of the plats on the farm first occupied by the Amarillo Cereal Field Station, Amarillo, Tex.

tinuous cropping and summer fallowing by various methods of farming, and to conduct rotations which are not necessarily practical but which bring out the residual effect of preceding crops and of cultivation. A study of the influence of fall and spring plowing on crop yields is also included. The Office of Dry-Land Agriculture furnished a man to be in direct charge of their experiments.

The Office of Biophysical Investigations installed a number of instruments for obtaining meteorological data and making soil moisture determinations in connection with crop production. This work is very closely associated with that of the Office of Dry-Land Agriculture. The offices of Forage-Crop Investigations, Sugar-Plant Investigations, Corn Investigations, and Field Investigations in Pomology also have conducted cooperative work with the Office of Cereal Investigations at Amarillo. The last line of cooperative work inaugurated was with the Office of Field Investigations in Pomology in determining suitable varieties of fruit trees for the Panhandle region. A few apple, crab apple, plum, and cherry trees were set in the spring of 1911 and the area has since been considerably increased. The work with alfalfa and sugar beets has been discontinued by the



FIG. 9.—General view of the small-grain nursery and field plats on farm No. 2 occupied by the Amarillo Cereal Field Station, Amarillo, Tex.

offices having charge of those crops. All these cooperating offices have allotted funds in support of the work conducted by them.

In addition to the work at Amarillo, the Office of Cereal Investigations has conducted some experiments with grains at Chillicothe, Tex., in cooperation with the Office of Forage-Crop Investigations, and also at Dalhart, Tex., with the Office of Dry-Land Agriculture. The results of the experiments at these two places are given separately after the report on the Amarillo work.

SCOPE AND EXTENT OF THE EXPERIMENTS.

The work at Amarillo was quite extensive for the year 1906, although that was the first crop year. The soil was indifferently prepared and therefore very difficult to cultivate. The larger proportion of the experiments were varietal tests of the different cereals. There were some rate-of-seeding and date-of-seeding tests and some cultivation

experiments. There were 329 crop tests in field plats and 1,186 tests in nursery rows. In addition to these, 109 plats were used by the Office of Dry-Land Agriculture. Though quite large, the number of varieties grown was much smaller than the number of tests made.

The scope of the work has gradually broadened with the passing of the years. Lines of work that have given most promise of success have been increased. The grain sorghums now rank first in the space required for experimentation as well as in the yields of grain. New varieties are being tested and the better varieties are being improved by selection and breeding. This is true not only of the sorghums but of all the cereals now grown. More attention is given to rates and dates of seeding, time and depth of plowing, and subsequent cultivation.

Permanent environmental experiments have been inaugurated. These are known as trilocal experiments and are now conducted with winter wheat, oats, milo, kafir, and Sudan durra. The object of these experiments is to determine the change in chemical composition due to environment, and incidentally to test the value of home-grown seed in comparison with that grown at some distant place.

During the year 1911 there were 380 crop tests in field plats and 1,451 tests in nursery rows, besides the 123 tenth-acre plats used in permanent experiments for the Office of Dry-Land Agriculture.

NURSERY TESTS WITH SMALL GRAINS.

The detailed results from the nursery work are not given in this bulletin. It may be well, however, to outline briefly the system under which this part of the work is done, which is as follows:

Series A consists of short rows, each grown from an individual selected head. These are planted by hand. New varieties, introductions, local sorts, etc., are generally grown in small plats, and heads are selected from these plats and grown in head rows in series A; or head selections may be made from plats of varieties already being tested on the farm. Series A plantings of small grains at Amarillo in 1909 are shown in figure 10, with some of the larger plantings in the background.

Series B consists of rows of definite length (15 feet) planted with bulk seed from the rows in series A by means of a garden drill. This is the second generation from selected individual heads. From these rows comparative yield tests are obtained. The poorer sorts are continued in series B another year or are discarded, while the better ones are carried forward to series C.

Series C consists of two rows, each 2 rods long, planted by means of a garden drill with bulk seed from the better rows of the B plantings of the previous year. Comparative tests are obtained. The poorer strains are given another trial in the same series or are discarded. The better ones are carried forward to series D.

Series D consists of increase plats grown from seed of the best strains in series C and planted with an ordinary grain drill. Comparative tests are again obtained, as

well as fairly accurate acre yields. The seed from desirable strains in series D is sufficient to permit testing the grain in field plats.

Series E consists of field plats of varying size, usually one-tenth acre each, planted with a grain drill with seed from the plats in series D.

Very careful detailed agronomic notes are taken on all these series, especially on series A, B, and C.

VARIETAL EXPERIMENTS WITH WINTER CEREALS.

The yields of the winter cereals at Amarillo from 1906 to 1911, inclusive, are given in Table XIX. It will be noted that the crop of 1906 was uniformly good. The fall of 1905 was very wet and there continued to be plenty of moisture during the winter and spring of 1906. The crop of 1907 was grown under more severe climatic conditions, but in spite of this fact gave promise of making good



FIG. 10.—The small-grain nursery and a portion of the experimental plats of the Amarillo Cereal Field Station, Amarillo, Tex., in 1909.

yields until it was cut short by a severe hailstorm on June 3. The hail damage was estimated at 75 per cent. Actual yields, however, were used in the table and in computing averages. The crop of 1908 was checked in its growth by a severe drought in the spring, but fairly good yields were obtained. In 1909 the crop was almost a total failure. The seed germinated in the fall, but there was not enough moisture in the soil to carry the plants through the dry winter and spring. The 1910 crop was raised under conditions quite similar to those of 1909, though somewhat less severe. The almost total failure of the 1911 crop was due to the fact that there was not enough moisture in the soil to germinate the seed until late in February and a very severe drought in June killed a large proportion of the plants.

TABLE XIX.—*Annual and average yields of winter small grains in field plats at Amarillo, Tex., for the six years from 1906 to 1911, inclusive.*

C. I. No.	S. P. I. No.	Kind of grain.			Yield of grain per acre (bushels).						
		Name.	Description.	Source.	1906	1907	1908	1909	1910	1911	Average.
		WHEAT.									
1558	11610	Turkey.....	Hard red.....	Russia..	25.75	3.26	23.23	0	10.17	1.58	10.66
1395-2		Diehl Mediterranean.	Medium hard red.....	Kansas..	18.50	1.41	25.83	0	10.42	.38	9.42
1667	7787	Beloglina.....	Hard red.....	Russia..	24.25	3.77	14.33	0	10.88	1.88	9.18
2208	9125	Kharkof.....	do.....	do.....	21.92	2.75	14.33	12.83	8.38	1.58	8.68
1436	5635	Crimean.....	do.....	do.....	17.62	2.66	17.00	0	7.00	2.13	7.73
1561	5407	Theiss.....	do.....	Hungary	24.91	1.70	8.16	0	7.96	2.15	7.48
1564	5500	Pesterboden.....	do.....	do.....	25.20	1.70	7.83	0	7.96	1.83	7.42
1437	5636	Crimean.....	do.....	Russia..	20.95	3.00	* 0	0	10.38	2.00	7.26
2239	9358	Beloglina.....	do.....	do.....	20.09	3.60	9.10	0	8.64	2.17	7.26
1563	5499	Weissenberg.....	do.....	do.....	21.00	4.34	9.18	0	7.21	1.67	7.23
2900-2		Mediterranean.....	Medium hard red.....	Central Texas.	21.91	1.74	11.09	0	4.71	(*)	7.89
(3)			do.....	Algeria..	19.37	1.41	12.83	0	0	(*)	6.72
1596	7582	Pretes.....	do.....	Russia..	20.36	0	9.00	0	2.88	(*)	6.45
2398	9872	Galgalos.....	Medium hard white.								
2902		Mammoth Red.....	Hard red.....	Texas.....		2.90	21.00	7.55	7.00	3.29	8.35
2223	11229	Turkey.....	do.....	Russia..		2.90	23.08	0	10.92	1.92	7.76
2842	17994	Rieti.....	Medium hard red.....	Italy.....		4.61	14.88	0	5.38	6.79	6.38
2902	7430	Jejar.....	Hard red.....	Spain.....		7.27	21.66	0	0	0	6.11
2900-1		do.....	do.....	do.....		1.95	5.83	6.66	6.58	0	5.25
2901		Mediterranean.....	Medium hard red.....	Texas.....		2.90	14.66	0	0	0	5.85
2903		White-chaff Mediterranean.	do.....	do.....		2.90					
294		do.....	do.....	do.....		4.53					
		SPELT. ¹									
1772		Red Winter.....	do.....	Washington.	49.68	14.39	50.38	0	15.20	20.80	25.07
		EMMER. ²									
2337		Black Winter.....	do.....	France..	45.43	8.07	30.75	0	24.10	9.50	19.64
2483-2		do.....	do.....	Germany.		13.59	22.82	2.79	23.30	9.00	14.30
		BARLEY.									
257		Tennessee.....	do.....	Tennessee.	23.93	0	22.49	0	3.13	14.11	10.61
		RYE.									
114		Kansas.....	do.....	Kansas..	20.89	1.58	15.66	5.00	6.43	4.87	9.07
34		Ivanov.....	do.....	Russia..	19.37	.63	13.66	2.66	4.82	4.82	7.66
		OATS.									
274	16864	Snoma.....	Brown.....	West Virginia.		4.03	15.31	0	0	0	4.83
273	12878	Culberson.....	White.....	Texas.....		3.81	12.50	0	0	0	4.07
442		Dun.....	Brown.....	New Zealand.			6.87	0	0	0	2.29
480		Boswell Winter.....	Black.....	Utah.....			3.75	0	0	0	1.25
		Winter Turf.....	Brown.....	Texas.....				0	0	0	

¹ Average of 2 fallow plats, 1909, hence not comparable.² Killed by hot-water treatment for smut.³ No. 2900-2 grown as No. 2900 in 1906. It was then hand selected and divided, No. 2900-1 being a hard red and No. 2900-2 a medium hard red, like the bulk of No. 2900. The yields of No. 2900 in 1906 and No. 2900-2 for 1907 to 1911, inclusive, have been averaged under No. 2900-2.⁴ Discarded after 1910 crop; average for 5 years only.⁵ Sown at the rate of 6 pecks per acre.⁶ Discontinued as winter crop after 1910; average for 5 years only.⁷ Sown at the rate of 4 pecks per acre.⁸ Yields figured on a weight of 25 pounds to the bushel.

Winter wheat.—The winter wheats that have done best are the hard red type, of which the Turkey (C. I. No. 1558) is a good exam-

ple. This is the leading variety in the tests at Amarillo. The Diehl Mediterranean (C. I. No. 1395-2) is a medium hard red wheat, which stands very close to the Turkey in point of yield. It has the advantage over Turkey of having longer straw, but on the other hand it has the disadvantage of shattering more if not harvested as soon as ripe. The other hard red winter wheats follow in the table in the order of their average yield. Fretes (C. I. No. 1596), a medium hard red, and Galgalos (C. I. No. 2398), a medium hard white, two of our best spring wheats, were grown also as winter varieties for a number of years, but after 1910 were discontinued as winter sorts and grown only as spring wheats. Many other varieties not given in the table have been tested and discarded. Some of the durum varieties have been tested from fall seeding, but with poor success. The winter-wheat plats have always been seeded at the rate of 3 pecks to the acre.

Winter spelt and emmer.—Spelt and emmer are closely related to wheat, but are grown for feed and not for making flour. They are similar in feeding value to oats and are used for much the same purposes. The straw is of little value as feed. These grains are not as hardy as winter wheat and should be sown slightly earlier than that cereal. They have been seeded at the rate of 5 pecks to the acre in these tests. The yields reported are figured on a weight of 25 pounds to the bushel. Red Winter spelt (C. I. No. 1772) has produced an average yield of 25.07 bushels (626 pounds) to the acre for the six years. This is a greater yield than was produced by any other feed grain in these tests. Black Winter emmer (C. I. No. 2337) has not yielded quite as well as the Red Winter spelt, but the grain has a lighter and softer hull, making it a slightly more desirable feed.

Winter barley.—The Tennessee Winter (C. I. No. 257) is the only winter barley that has given promise of being of value for this section. The average yield to the acre for the six years was 509 pounds (10.6 bushels), as compared with 640 pounds for Turkey wheat and 503 pounds for Kansas rye. Barley is not as winter hardy as wheat and should be sown earlier. It has been seeded at the rate of 5 pecks to the acre.

Winter rye.—Winter rye is more hardy than winter wheat, but does not equal that grain in yield. It nearly always comes through the winter in good shape and makes a vigorous growth in the spring. It also makes fine early spring pasturage. The highest average yield of grain, 9.07 bushels, has been produced by C. I. No. 114, a variety originally obtained from Kansas.

Winter oats.—Winter oats has not been a success. In 1908 two varieties produced fair yields, but not enough to make oats a profit-

able crop even if such yields could be obtained frequently. All the varieties under test winterkilled in 1909 and 1910, leaving no seed for planting in 1911.

CULTURAL EXPERIMENTS WITH WINTER WHEAT.

RATE-OF-SEEDING TESTS.

The results of the rate-of-seeding experiments are given in Table XX. These results are not exactly comparable in all the details, but the data have been arranged so as to have as few varying factors as possible. The average of all the tests is in favor of the lightest seeding, though this was not the case each year. Three pecks to the acre is the rate which is recommended under average conditions. With a good seed bed and good, clean seed 2 pecks or even $1\frac{1}{2}$ pecks to the acre might be sufficient, though in favorable seasons heavier seeding would produce larger yields. The plats in this test were sown September 26, 1906, October 10, 1907, October 27, 1909, and November 16, 1910.

TABLE XX.—Yields obtained in rate-of-seeding tests with winter wheat at Amarillo, Tex., in 1907, 1908, 1910, and 1911.

C. I. No.	Year and variety.	Rate of seed- ing.	Yield per acre (bushels).			Remarks.
			Light seed- ing.	Medi- um seed- ing.	Heav- ier seed- ing.	
2208	1907.	Pecks.				
	Kharkof.....	$\left\{ \begin{array}{l} 3 \\ 3\frac{1}{2} \\ 4 \end{array} \right.$	2.75	1.83	1.50	Every drill row. Do. Do.
	Average.....		2.75	1.83	1.50	
2339	1908.					
	Beloglina.....	$\left\{ \begin{array}{l} 1\frac{1}{2} \\ 3 \\ 3 \end{array} \right.$	12.66	8.16	6.50	Every other drill row. Every drill row. Every other drill row.
	Average.....		12.66	8.16	6.50	
2223	1910.					
	Turkey.....	$\left\{ \begin{array}{l} 1\frac{1}{2} \\ 3 \\ 1\frac{1}{2} \end{array} \right.$	6.50	10.92		Do. Every drill row. Every other drill row.
	1558 do.....	$\left\{ \begin{array}{l} 3 \\ 4 \\ 1\frac{1}{2} \end{array} \right.$	5.03	8.79	9.42	Every drill row. Do. Every other drill row.
	2208 Kharkof.....	$\left\{ \begin{array}{l} 3 \\ 4 \\ 4 \end{array} \right.$	4.50	6.00	7.75	Every drill row. Do.
1558	Average.....		5.54	8.57	8.58	
	1911.					
	Turkey.....	$\left\{ \begin{array}{l} 3 \\ 4 \\ 3 \end{array} \right.$		1.58	1.54	Do. Do.
2208	Kharkof.....	$\left\{ \begin{array}{l} 3 \\ 4 \end{array} \right.$		1.63	2.17	
	Average.....			1.60	1.85	

DATE-OF-SEEDING TESTS.

The results of the different dates of seeding for winter wheat are presented in Table XXI. The results are strictly comparable, as the only varying factor in any one year is the date of seeding. The medium seeding for 1907 and the early seeding for 1908 are lacking. In the fall of 1910 the plats in this test were sown at the usual time, but owing to lack of moisture in the soil none of the seed germinated till the following spring, making the results valueless in this test; hence, the 1911 figures are not included. The latest seedings here given show the best average results. The time recommended for seeding winter wheat is from October 15 to November 1.

TABLE XXI.—*Yields obtained in date-of-seeding tests with winter wheat at Amarillo, Tex., in 1907, 1908, and 1910.*¹

C. I. No.	Year and variety.	Date of seeding.	Yield per acre (bushels).		
			Early seed- ing.	Med- ium seed- ing.	Late seed- ing.
1558	1907.	1906.			
	Turkey.....	{Sept. 26 Nov. 3	3.26		7.80
	Average.....		3.26		7.80
1667	1908.	1907.			
	Beloglina.....	{Oct. 10 Nov. 2		13.50	15.41
	Weissenberg.....	{Oct. 10 Nov. 2		7.36	11.00
1395-2	Diehl Mediterranean.....	{Oct. 10 Nov. 2		21.66	30.00
2943	Hard red winter.....	{Oct. 10 Nov. 2		9.66	12.66
	Average.....			13.04	17.27
	1910.	1909.			
1395-2	Diehl Mediterranean.....	{Oct. 4 22 Nov. 5	10.42	9.88	8.96
	Beloglina.....	{Oct. 4 22 Nov. 5	10.54	10.88	10.50
	Rieti.....	{Oct. 4 22 Nov. 5	5.38	Failed.	Failed.
1558	Turkey.....	{Oct. 4 22 Nov. 5	11.67	10.17	10.50
	Kharkof.....	{Oct. 4 22 Nov. 5	10.71	8.38	8.58
	Average.....		9.74	7.86	7.71

¹ The 1911 test was seeded in the fall of 1910 on the usual dates, but owing to lack of moisture in the soil none of it germinated until about March 1, 1911. For this test it was an entire failure.

DATE-OF-PLOWING AND DATE-OF-SEEDING TESTS.

Table XXII presents the results of a test of different dates of plowing and seeding with Kharkof wheat (C. I. No. 2208). The seed was sown at the rate of 3 pecks to the acre. In this test early plow-

ing and late seeding gave the highest yield. The long interval between plowing and seeding seems to be the factor largely responsible for the increase obtained. This table also indicates that when the land is prepared just before seeding, deep plowing does not give as good results as shallow preparation. Good preparation, as the term is used in this bulletin, means plowing to a depth of 6 inches or more, while poor preparation means plowing or disking that stirs the soil to a depth of 3 inches or less.

In a further test, Turkey wheat (C. I. No. 1558), seeded at the rate of 3 pecks to the acre, was used (Table XXII). The longer interval between plowing and seeding gave the best results in all cases. Where the seeding was done shortly after the preparation of the land the best results were secured by disking. The disking stirs the surface soil only and leaves the subsoil compacted; no time is then required for the soil to settle. Good plowing is best done early in the summer. The latest seeding gave the best results in each case.

TABLE XXII.—*Yields obtained in date-of-plowing and date-of-seeding tests with Kharkof and Turkey winter wheats at Amarillo, Tex., in 1908.*

KHARKOF WINTER WHEAT.

Date of plowing.	Date of seeding.	Interval between plowing and seeding.	Kind of preparation.	Yield per acre.
1907.	1907.	Days.		Bush.
Aug. 12.....	Nov. 2.....	82.....	Good.....	17.00
Aug. 9.....	Oct. 8.....	60.....	do.....	14.33
Sept. 25.....	do.....	13.....	do.....	11.66
Oct. 8.....	do.....	None.	Poor.....	12.66

TURKEY WINTER WHEAT.

Date of seeding.	Plowed Aug. 14.	Plowed Sept. 6.	Double disked Aug. 20 and Sept. 6.	Average yield for date of seeding.
1907.	Bush.	Bush.	Bush.	Bush.
Sept. 14.....	6.0	6.2	9.1	7.1
Oct. 10.....	5.7	7.0	9.8	7.5
Do.....	8.8	14.6	13.8	12.4
Nov. 2.....	26.0	22.1	21.6	23.2
Average yield for date of plowing.....	11.62	12.47	13.57	

In 1906 some additional information relative to the preparation of land for fall-sown small grains was obtained. Plats of Fretes (C. I. No. 1596), a common spring wheat, and Kubanka (C. I. No. 2246), a durum spring wheat, were sown in the fall of 1905 on sod land that had been broken the previous summer. Plats for each variety were double

disked before seeding, while others were deeply replowed just previous to sowing the seed. The disked plat of the Fretes wheat yielded at the rate of 19.37 bushels to the acre, while two fall-plowed plats averaged 10.74 bushels. Similar results were obtained from the Kubanka durum wheat, the disked plat yielding 13.41 bushels and the fall-plowed plat 6 bushels.

From these tests it is apparent that best results may ordinarily be obtained from seeding winter wheat about October 15 to November 1, on land that has been plowed the previous summer and given good cultivation to conserve the moisture. Thorough disking is to be preferred to plowing when the land is not prepared till near seeding time.

SOIL-PREPARATION TESTS.¹

In Table XXIII will be found the annual and average yields obtained in a test of the different methods of soil preparation for winter wheat. The variety used in this test was Kharkof (C. I. No. 2208).

TABLE XXIII.—*Annual and average yields obtained in soil-preparation tests with winter wheat at Amarillo, Tex., for the years 1907, 1908, 1909, and 1911.*¹

Preparation and condition of the field.	Yield per acre (bushels).				
	1907	1908	1909	1911	Average.
Shallow fall plowing after winter wheat.....	1.66	12.66	0	3.80	5.48
Deep fall plowing after winter wheat.....	1.41	14.33	0	3.80	6.04
Clean-tilled summer fallow.....	2.33	16.91	2.83	4.80	8.18
Deep fall plowing and subsoiled after winter wheat..	2.08	16.50	0	1.20	5.90
Listed after winter wheat and dragged level during summer.....	3.41	15.33	0	2.20	5.84
Diaked and stubbled in after corn.....	2.75	11.66	0	1.20	4.28
Rye turned under and kept cultivated.....	² 2.18	15.00	0	2.07	5.69
Cowpeas turned under and kept cultivated.....	2.66	12.66	0	⁴ 2.16	4.94

¹ The 1910 crop is not included, as it was on new land which was all treated alike.

² The 1907 crop is not included in the averages, as it was severely damaged by hail. Actual yields are given; the estimated damage was 75 per cent.

³ Sorghum instead of rye was turned under in 1906.

⁴ Canada field peas instead of cowpeas were turned under in 1910.

ENVIRONMENTAL EXPERIMENT.

The object of this experiment, which is conducted in cooperation with the Bureau of Chemistry of the United States Department of Agriculture, is primarily to determine the influence of environment on the chemical composition of winter wheat, comparing continuously home-grown seed with that grown at certain widely separated stations. Not only is the chemical composition determined, but the

¹ The soil-preparation tests are conducted cooperatively by the Office of Dry-Land Agriculture under the direction of Prof. E. C. Chilcote, Agriculturist in Charge. The results of these tests with winter wheat, spring wheat, oats, barley, corn, milo, and kafir are presented in Tables XXIII, XXVIII, XXXII, XXXVI, XL, and XLII, respectively. In all these tables the term "deep plowing" is used to describe plowing 8 inches deep, while the term "shallow plowing" refers to plowing 3 inches deep. These tables are presented as a part of the cereal experiments of the farm. No discussion of the results is included, since the data have already been presented in Bulletin 187 of the Bureau of Plant Industry.

yield, color, and hardness of the grain as well. Only the data on yield are presented in Table XXIV. In two of the three years for which data are presented, home-grown seed yielded more than that obtained from elsewhere. In only one case, that of the California seed in 1911, has the yield from other seed exceeded that from home-grown seed. A satisfactory explanation can not be given for this instance, though the fact that all seed planted in the fall of 1910 failed to germinate until about March 1 following may have been a factor.

TABLE XXIV.—*Annual and average yields obtained in an environmental experiment with winter wheat at Amarillo, Tex., from 1907 to 1911, inclusive.*

Where seed was grown.	Yield per acre (bushels).					
	1907	1908	¹ 1909	1910	1911	Average.
Amarillo, Tex. (home grown).....	3.00	0	No seed.	10.38	2.29	3.92
Marysville, Cal.....	2.68	0	0.16	6.29	6.75	3.93
Hays, Kans.....	2.08	0	.66	6.58	2.04	2.67

¹ Not included in the averages.

This experiment was started with seed of the Crimean (C. I. No. 1437), a hard red winter wheat, grown at Hays, Kans., in 1905. It was grown at the three points mentioned in the table in 1906 and seed sent from each to the other two. This method of sending seed from the home-grown plat at each place to the other two places is followed each year. The following exceptions must be noted: The seed planted at Amarillo, Tex., in the fall of 1907 was given the hot-water treatment for smut and failed to germinate. This left Amarillo without home-grown seed. Seed was received from the other two points in the fall of 1908 and planted at Amarillo, but no seed was sent from Amarillo to the other points. The yield at Amarillo in 1909 was so small that there was no seed to send to the other two points. All the home-grown seed at Amarillo was planted on one plat. This closes the gap at Amarillo, but not until 1911 did the other two points have crops again from Amarillo seed. Seeding dates were September 26, 1906; October 10, 1907; November 2, 1908; October 23, 1909; and November 12, 1910. The rate of seeding was 3 pecks per acre. The station in California has been changed from Marysville to Davis, but as both are in the Sacramento Valley and not far apart the change did not affect this experiment.

EXPERIMENTS WITH SPRING SMALL GRAINS.

The experiments with spring small grains have included tests of wheat, oats, barley, proso, flax, and buckwheat. A large number of varietal tests have been conducted, while cultural experiments

with the more important cereals have been given considerable attention. In the following pages these are reported separately for each cereal.

EXPERIMENTS WITH SPRING WHEAT.

VARIETAL TESTS.

The yields obtained from varietal tests of common and durum spring wheat are presented in Table XXV, the durum varieties being listed first.

TABLE XXV.—*Annual and average yields obtained in varietal tests with spring wheats at Amarillo, Tex., for the years 1906 to 1911, inclusive.*

C. I. No.	S. P. I. No.	Name.	Origin.	Yield of grain per acre (bushels).						
				1906	1907	1908	1909	1910	1911	Average.
		DURUM WHEATS.								
2235	9324	Marouani ¹	Algeria.....	5.33	10.40	16.83	5.66	2.75	11.63	8.77
2228	9130	Saragolla ¹	Italy.....	7.61	8.45	15.33	6.50	2.71	11.13	8.62
2246	10364	Kubanka ¹	Russia.....	8.04	4.30	16.83	5.85	3.06	9.33	7.90
1583	7578	Marouani ²	Algeria.....	6.42	6.25	15.86	.....	5.67	9.57	8.75
2941	.....	.....	.....	5.91	7.75	19.00	.....	.....	.....	10.88
2882	15788	Kubanka.....	Russia.....	6.83	6.20	15.66	.....	.....	.....	9.56
1597	7579	Medeah.....	Algeria.....	6.87	5.56	14.00	.....	.....	.....	8.81
2100	13865	Black Don.....	Russia.....	5.16	5.01	15.00	.....	.....	.....	8.39
2834	.....	.....	.....	5.54	8.01	.....	.....	.....	.....	.....
2247	9479	Velvet Don.....	Russia.....	.....	7.56	15.16	.....	.....	.....	.....
2087	7793	Mohammed ben Bachir.....	Algeria.....	.....	11.50	18.00	.....	.....	.....	.....
2008-III*	.....	.....	.....	.....	.....	16.50	.....	4.58	10.30	10.46
2091-III	.....	.....	.....	.....	.....	14.66	.....	3.50	10.50	9.55
2091-IX	.....	.....	.....	.....	.....	14.66	.....	3.71	6.54	8.30
2094-III	.....	.....	.....	.....	.....	.....	13.66	3.19	11.23	9.36
2099-I	.....	.....	.....	.....	.....	.....	7.83	4.29	14.83	8.98
2096-I	.....	.....	.....	.....	.....	.....	6.83	3.13	12.58	7.18
2221	.....	.....	.....	.....	.....	.....	7.50	2.29	11.21	7.00
2098-II	.....	.....	.....	.....	.....	.....	3.33	4.33	12.88	6.84
2537-I-II	.....	.....	.....	.....	.....	.....	2.66	3.00	13.29	6.31
2089-VI	.....	.....	.....	.....	.....	.....	3.00	3.50	11.83	6.11
2088-VIII	.....	.....	.....	.....	.....	.....	3.00	4.08	9.67	5.58
2090-V	.....	.....	.....	.....	.....	.....	2.00	4.29	10.08	5.45
2089-III	.....	.....	.....	.....	.....	.....	2.33	3.33	10.21	5.29
2087-II	.....	.....	.....	.....	.....	.....	.....	5.88	9.67	7.77
2087-III	.....	.....	.....	.....	.....	.....	.....	4.92	8.83	6.87
2222-V	.....	.....	.....	.....	.....	.....	.....	3.13	10.46	6.79
2222-VI	.....	.....	.....	.....	.....	.....	.....	3.04	10.17	6.60
2091-XI	.....	.....	.....	.....	.....	.....	.....	3.67	7.63	5.65
2077	.....	.....	.....	.....	.....	.....	.....	.....	9.04	.....
1576	.....	.....	.....	.....	.....	.....	.....	.....	7.54	.....
		COMMON WHEATS.								
1596	7582	Fretes.....	Algeria.....	5.08	10.68	19.50	8.50	3.56	9.04	9.39
2398	9872	Galgalos.....	Russia.....	4.90	10.56	18.00	7.50	3.92	10.98	9.31
2227	15802	Chul.....	Turkestan.....	6.08	5.53	(⁶)	3.50	3.52	8.71	5.46
2307	9871	Erivan.....	Russia.....	3.55	8.43	(⁶)	.....	.....	.....	.....
2085	7585	Black Potlard.....	Algeria.....	4.02	.....	.....	.....	.....	.....	.....
2946	.....	Barley wheat.....	Transvaal.....	2.83	.....	.....	.....	.....	.....	.....

¹ Grown from selected seed 1909 to 1911, inclusive.

² Grown from selected seed 1910 and 1911.

³ Roman numerals following a Cereal Investigation number indicate selections from the original grain of that number.

⁴ Average of six check plots.

⁵ Thrown out in 1906 on account of being very badly smutted.

It will be seen from the table that a much larger number of varieties of durum than of common spring wheat have been tested. Only three durum and two common wheats have been grown during the full period of six years. The two common wheats (Fretes, C. I. No. 1596; and Galgalos, C. I. No. 2398) made better average yields than any of the durums (Marouani, C. I. No. 2235; Saragolla, C. I. No. 2228; and Kubanka, C. I. No. 2246), but were slightly lower in yield than the two best winter wheats (Turkey, C. I. No. 1558, and Diehl Mediterranean, C. I. No. 1395-2).¹ This leads to the conclusion that for the Panhandle region the groups of wheat rank in the following order: (1) Winter wheat, (2) common spring wheat, and (3) durum wheat. The Fretes is a medium hard red wheat, while the Galgalos would be classed as a medium hard white variety.

RATE-OF-SEEDING TESTS.

Experiments have been conducted each year in an effort to determine the proper rates of seeding for spring wheat. The results will be found in Table XXVI for the years 1906, 1908, 1909, 1910, and 1911. One criticism that might be made of this series of tests is that it has not been uniform in that the same varieties and the same rates of seeding have not been used each year. On the whole, however, the indications are that 4 pecks to the acre for the common wheats and 5 pecks for the durum wheats are the rates at which they should be seeded ordinarily. The weather conditions, the condition of the seed bed, and the viability of the seed all have such important effects on the crop that they must all be taken into consideration in determining the rate at which it is best to seed a given field.

TABLE XXVI.—Yields obtained in rate-of-seeding tests with spring wheat at Amarillo, Tex.

1906.

C. I. No.	S. P. I. No.	Variety.	Kind of wheat.	Rate of seed-ing.	Yield per acre.	C. I. No.	S. P. I. No.	Variety.	Kind of wheat.	Rate of seed-ing.	Yield per acre.
				Pecks.	Bush.					Pecks.	Bush.
2228	9130	Saragolla....	Durum	5	7.61	2227	15802	Chul.....	Common	4	6.09
				6	6.70					6	4.72
1597	7579	Medeah.....	do.....	4	6.62	2398	9872	Galgalos.....	do.....	4	4.90
				7	6.87					6½	3.42
1593	7578	Marouani.....	do.....	7	5.46	2946		Sonora.....	do.....	3½	1.95
				8	4.12					4	2.83
2941			do.....	4	5.41	2085	7585	Black Poulard.	Poulard.	4	4.02
				6	5.91					7	3.14
2235	9324	Marouani.....	do.....	6	3.83						
				8	5.33						

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¹ See p. 42.² Average of two plats.

TABLE XXVI.—Yields obtained in rate-of-seeding tests with spring wheat at Amarillo, Tex.—Continued.

1908.

C. I. No.	S. P. I. No.	Variety.	Kind of wheat.	Yield per acre (bushels).		
				Seeded at 4-peck rate.	Seeded at 5-peck rate.	Seeded at 6-peck rate.
1593	7578	Marouani.....	Durum.....	.....	15.86	14.26
2087	7793	Mohammed ben Bachir.....	do.....	.....	18.00	16.06
1596	7582	Frete.....	Common.....	17.33	16.53	.....
2398	9872	Galgalo.....	do.....	15.73	14.26	.....
Average of 2 varieties durum wheat.....				.....	16.93	15.46
Average of 2 varieties common wheat.....				16.53	15.39	.....

1909.

C. I. No.	Variety.	Rate of seeding.	Space between rows. ¹		Yield per acre.
			Pecks.	Inches.	
2398	Galgalo.....	{	1½	12	0
			3	6	4.33
			4	6	5.16
			5	6	4.83

1910.

C. I. No.	S. P. I. No.	Variety.	Kind of wheat.	Yield per acre (bushels).		
				Seeded at 3-peck rate.	Seeded at 4-peck rate.	Seeded at 5-peck rate.
2246	10364	Kubanka.....	Durum.....	2.92	2.83	2.96
2398	9872	Galgalo.....	Common.....	4.42	3.58	3.50

1911.

2235-I	9872	Marouani.....	Durum.....	14.42	14.50	10.58
2398		Galgalo.....	Common.....	12.00	13.08	.....

¹ Where the rows were 12 inches apart weeds started between the rows and choked the wheat. Where the rows were 6 inches apart the wheat kept ahead of the weeds, which did not grow large.

DATE-OF-SEEDING TESTS.

The proper date on which spring wheats should be sown in the Panhandle region depends so much upon the amount of moisture in the soil that no very definite conclusion can be drawn. The time of seeding ranges from the last of February to about the middle of April. If there is plenty of moisture in the soil early seeding is recommended. If the soil moisture is deficient, later seeding will probably give better results. In 1908 (Table XXVII) larger yields were obtained from the later seeding, while in 1910 the opposite was true. The difference in 1910, however, was very slight.

TABLE XXVII.—Yields obtained in date-of-seeding tests with spring wheat at Amarillo, Tex., in 1908 and 1910.

1908.						1910.					
C. I. No.	S. P. I. No.	Variety.	Kind of wheat.	Yield per acre (bushels).		C. I. No.	Variety.	Kind of wheat.	Yield per acre (bushels).		
				Sown Feb. 28.	Sown Mar. 16.				Sown Mar. 14.	Sown Apr. 1.	
2235	9324	Marouani	Durum....	16.33	16.83	1596	Frete.....	Common.	3.56	3.79	
2398	9872	Galgos	Common..	15.83	18.00	2398	Galgos.....	do.....	3.92	2.08	
						2228-I	Sargolla....	Durum..	2.71	3.50	
						2235-I	Marouani....	do.....	2.75	3.63	
						2094-III	Kubanka.....	do.....	3.12	2.67	
Average.....				16.08	17.41					3.21	3.13

¹ Average of two plats.

SOIL-PREPARATION TESTS WITH DURUM WHEAT.

In Table XXVIII, the data obtained at Amarillo in the soil-preparation tests for spring wheat conducted by the Office of Dry-Land Agriculture are presented.¹ In 1907, Kubanka (C. I. No. 2246) was used, while in 1908 and succeeding years Saragolla (C. I. No. 2228) was grown.

TABLE XXVIII.—Annual and average yields obtained in soil-preparation tests with durum wheat at Amarillo, Tex., for the years 1907, 1908, 1909, and 1911.¹

Preparation and condition of the field.	Yield per acre (bushels).				
	* 1907	1908	1909	1911	Average.
Shallow spring plowing after spring wheat.....	2.50	17.00	0	7.30	8.10
Deep spring plowing after spring wheat.....	1.83	15.33	0	11.40	8.91
Deep fall plowing after spring wheat.....	1.06	14.00	2.83	10.00	8.94
Clean-tilled summer fallow.....	2.83	16.50	10.00	18.52	15.01
Deep fall plowing and subsoiled after spring wheat.....	2.16	16.16	4.00	11.30	10.48
Listed after spring wheat and dragged level during summer.....	1.91	14.33	0	12.96	9.07
Disked and stubbled in after corn.....	1.00	8.33	0	12.10	6.81
Deep spring plowing after corn.....	2.83	8.00	0	11.60	6.53
Deep fall plowing after corn.....	1.41	8.50	0	5.70	4.73
Deep fall plowing after oats.....	1.00	13.36	0	6.20	6.52
Deep spring plowing after oats.....	1.33	5.33	0	6.80	4.04
Cowpeas turned under and kept cultivated.....	2.50	19.66	0	* 11.40	10.35
Rye turned under and kept cultivated.....	* 1.58	14.16	4.33	7.50	8.66

¹ The 1910 crop is not included, as it was on new land which was all treated alike.² The 1907 crop is not included in the averages, as it was severely damaged by hail. The actual yields are given; the estimated damage was 75 per cent.³ Canada field peas instead of cowpeas were plowed under in 1910.⁴ Sorghum instead of rye was plowed under in 1906.

EXPERIMENTS WITH SPRING OATS.

VARIETAL TESTS.

Though not considered one of the leading crops of the Panhandle, spring oats have given uniformly better results than the other spring small grains. All yields are figured at 32 pounds per bushel, though

¹ See footnote on page 47.

the average test here is between 27 and 28 pounds. The results of the varietal tests are given in Table XXIX. The varieties are arranged in the table according to the number of years they have been grown and in the order of their average yields for those periods.

TABLE XXIX.—*Annual and average yields obtained in varietal tests with spring oats at Amarillo, Tex., for the years 1906 to 1911, inclusive*

C. I. No.	S. P. I. No.	Name.	Color of grain.	Origin.	Yield per acre (bushels).						
					1906	1907	1908	1909	1910	1911	Average.
286	12133	Red Algerian	Red	Algeria	15.96	17.59	38.12	17.81	11.41	17.86	19.62
458		Red Rustproof	do	do	19.76	19.30	32.65	19.68	8.98	17.81	18.03
286	15858	Red Algerian	do	Algeria	10.62	20.37	30.31	19.06	10.94	16.25	17.92
165	5938	Sixty-Day	Yellow	Russia	21.14	20.93	30.63	19.68	5.83	8.83	17.84
337	5168	Seventy-five Day	do	do	12.39	22.65	24.06	18.12	4.45	17.03	16.45
293	15856	Burt	Brown	do	13.33	16.15	23.43	16.56	7.97	18.67	16.01
459		Kherson	Yellow	Russia	11.51	15.15	20.62	19.06	4.53	16.72	14.59
293	16865	Burt	Brown	do	12.88	14.53	22.12	0	6.64	20.94	12.85
165	17720	Sixty-Day	Yellow	Russia		24.37	32.50	16.25	3.91	11.72	17.75
487	20370	Red Siberian	do	Siberia		14.65	31.87	17.81	10.08	6.64	16.21
293-VI		Selection from Burt	Brown	do		10.34	23.43	12.81	9.30	20.63	15.30
537	17451	Burt	do	do		6.87	24.75	8.75	6.95	20.55	13.57
535	17148	Kherson	Yellow	Russia		14.06	16.25	2.81			
165	15857	Sixty-Day	do	do		10.80	14.37				
293	11145	Burt	Brown	do		17.43	15.50				
336	10624	Belyak	Red	Russia		8.07	14.06				
254	8650	North Finnish Black	Black	Finland		15.00					
213	10330	Swedish Select	Yellow	Russia		9.30					
165-I		Selection from Sixty-Day	do	do		11.03		0	7.73	12.43	7.79

¹ Average of two plats.

Of the eight varieties which have been grown for the six years from 1906 to 1911, inclusive, the highest average yields have been obtained from Red Algerian (C. I. No. 286) and Red Rustproof (C. I. No. 458). Two plats of the latter variety were grown in 1907, 1908, 1909, and 1910. The failure of Burt (C. I. No. 293) in 1909 and the low yields of Red Rustproof (C. I. No. 458), Burt (C. I. No. 537), and Kherson (C. I. No. 535) the same year were due to the fact that they were planted on ground which had grown grain sorghum in 1908, while the other varieties followed durum spring wheat. If it had been grown under strictly comparable conditions that year, it is possible that the Red Rustproof (C. I. No. 458) might have equaled or exceeded the Red Algerian in yield. These two varieties are of much the same type. The Sixty-Day and the Seventy-five Day, two varieties from southern Russia, with small yellow kernels, have yielded slightly less than Red Algerian and Red Rustproof. None of the varieties grown for less than six years has yielded as well as those already mentioned, from averages including the same years.

RATE-OF-SEEDING TESTS.

The rate-of-seeding tests for spring oats have been carried on rather irregularly. As in similar tests with spring wheats, these experiments have not been conducted uniformly. The rates have been comparable for the individual years but not for the consecutive crops.

The results for 1906 (Table XXX) are in favor of the medium seeding for that year. This medium seeding was $2\frac{1}{2}$ times as much as the lighter seeding of 1908, which gave the best yields of any test that year. In 1911, the heavier rate produced the best average yield.

TABLE XXX.—Yields obtained in rate-of-seeding tests with spring oats at Amarillo, Tex., in 1906, 1908, and 1911.

C. I. No.	S. P. I. No.	Year and variety.	Rate of seed-ing.	Yield per acre.	C. I. No.	S. P. I. No.	Year and variety.	Rate of seed-ing.	Yield per acre.
		1906.					1906.		
			<i>Pecks.</i>	<i>Bush.</i>				<i>Pecks.</i>	<i>Bush.</i>
165	5938	Sixty-Day.....	9	21.14	254	8650	North Finnish Black	6	15.00
			13	19.64				9	11.78
458		Red Rustproof.....	9	19.76	293	16865	Burt.....	6	12.88
			13	19.45				9	11.40
293	11145	Burt.....	9	16.02	165	15857	Sixty-Day.....	6	10.23
			13	17.43				9	10.80
286	12133	Red Algerian.....	6	15.96	213	10330	Swedish Select.....	6	9.30
			13	11.82				13	7.85

C.I.No.	S.P.I. No.	Year and variety.	Yield per acre (bushels).		C.I.No.	S.P.I. No.	Year and variety.	Yield per acre (bushels).	
			Seeded at 4-peck rate.	Seeded at 6-peck rate.				Seeded at 5-peck rate.	Seeded at 6-peck rate.
		1908.					1911.		
165	5938	Sixty-Day.....	25.00	25.63	487	20370	Red Siberian.....	6.64	14.61
286	12133	Red Algerian.....	38.12	32.38	286	12133	Red Algerian.....	13.28	14.42
296	15858	.....do.....	30.31	29.37	296	15858	.....do.....	16.25	15.00
293	15856	Burt.....	21.12	21.56	165-1		Sixty-Day.....	13.98	15.00
458		Red Rustproof...	32.50	24.75					
458	19233	.....do.....	32.81	32.60					
Average.....			29.97	27.70				12.54	14.76

¹ An old road ran through this plat.

In 1906 the average yield of three varieties was 12.70 bushels to the acre from the 6-peck rate and 11.33 bushels from the 9-peck rate; the average of two varieties seeded at 6 and 13 pecks was 12.63 and 9.83 bushels for the respective rates of seeding; and the average of two varieties seeded at 9 and 13 pecks was 18.58 for the 9-peck and 18.53 bushels for the 13-peck rate. The Red Rustproof (C. I. No. 458) is not included in the latter averages, because the yield of this variety at the 13-peck rate is not comparable. In 1908 all the varieties were seeded at the uniform rates of 4 and 6 pecks to the acre. The six plats seeded at the rate of 4 pecks to the acre averaged 29.97 bushels, while those seeded at the rate of 6 pecks averaged 27.70 bushels, a difference of 2.77 bushels in favor of the 4-peck rate when the 2-peck difference in rate of seeding is taken into account. The four 5-peck plats averaged 12.54 bushels to the acre in 1911, while the four 6-peck plats averaged 14.76 bushels, a net

difference of 1.97 bushels to the acre in favor of the heavier rate of seeding. This difference, however, is due almost entirely to the low yield of the Red Siberian variety from the 5-peck seeding, for which there is no adequate explanation.

Although the results here shown are quite contradictory, it is the opinion of the writers that 5 pecks of good, clean seed to the acre is about the rate of seeding to recommend for spring oats. This opinion has been formed by noting the results in the varietal tests as well as in the regular rate-of-seeding tests.

DATE-OF-SEEDING TESTS.

Not very much work has been done with date-of-seeding tests of spring oats, this crop having generally been seeded as early in the spring as possible. When they have been sown early good results have nearly always been obtained. This was especially true in 1908, when nearly all the oat plats were seeded the latter part of February and early in March. In 1910 the early seeding gave very much better results than the later seeding (Table XXXI).

TABLE XXXI.—*Yields obtained in a date-of-seeding test with spring oats at Amarillo, Tex., in 1910.*

C. I. No.	S. P. I. No.	Variety.	Yield per acre (bushels).	
			Sown Mar. 9.	Sown Apr. 1.
165	17720	Sixty-Day.....	3.91	4.16
293	16865	Burt.....	7.97	4.77
286	12133	Red Algerian.....	11.41	5.47
458	19283	Red Rustproof.....	8.98	5.63
487	20870	Red Siberian.....	10.08	4.53
Average.....			8.47	4.91

It is probable that early to medium seeding will most often produce good yields, though there are conditions under which it would be advisable to seed rather late. In the annual report of the farm superintendent for 1909, the following instance is given which illustrates conditions that may arise:

In the spring of 1909 most of the seeding of small grains was done during the first two weeks in March. The spring was unusually dry, with high winds. On the morning of May 1 the thermometer registered 19° F. All the early spring plantings were very severely injured. This frost was followed by more high winds, which added materially to the damage already done. The particles of soil carried by the wind cut the growing crop to the ground in several portions of the farm. Later in the season the Office of Alkali and Drought Resistant Plant Breeding Investigations sent seeds of various kinds to Amarillo to be planted. Among these seeds were several varieties of wheat and oats. They were all planted on May 17 on fall-plowed wheat land. This planting escaped the frost and sustained very little, if any, injury from the

severe weather conditions which prevailed later. The late plantings made a better growth of straw than the early plantings, seemed to fill better, and ripened a little later. No yield tests were made from these late plantings, as they were grown in short rows.

SOIL-PREPARATION TESTS.

The results presented in Table XXXII are those obtained in the soil-preparation tests with spring oats conducted by the Office of Dry-Land Agriculture at Amarillo.¹ The variety used in these tests was Burt (C. I. No. 293).

TABLE XXXII.—*Annual and average yields obtained in soil-preparation tests with spring oats at Amarillo, Tex., for the years 1907, 1908, 1909, and 1911.*¹

Preparation and condition of the field.	Yield per acre (bushels).				
	1907	1908	1909	1911	Average.
Shallow spring plowing after oats.....	3.12	20.00	0	28.20	16.06
Deep fall plowing after oats.....	4.63	32.18	0	27.50	19.89
Clean-tilled summer fallow.....	6.79	32.49	24.37	36.15	31.00
Deep fall plowing and subsoiled after oats.....	4.53	28.12	0	19.20	15.77
Listed after oats and dragged level during summer.....	7.34	29.68	0	26.80	18.82
Disked and stubbled in after milo.....	1.65	19.21	0	25.80	15.00
Disked and stubbled in after kafir.....	1.87	16.40	0	26.65	14.35
Disked and stubbled in after corn.....	3.75	22.68	0	28.00	16.89
Deep fall plowing after spring wheat.....	3.69	26.66	14.33	26.40	22.46
Deep spring plowing after spring wheat.....	1.09	23.43	0	35.70	19.71
Deep spring plowing after corn.....	4.14	21.87	0	35.95	19.27
Deep fall plowing after barley.....	3.12	31.25	0	35.60	22.28
Rye turned under and kept cultivated.....	² 4.84	31.87	5.00	18.00	18.29
Cowpeas turned under and kept cultivated.....	5.78	27.50	8.43	⁴ 25.90	20.61

¹ The 1910 crop is not included, as it was on new land which was all treated alike.

² The 1907 crop is not included in the averages, as it was severely damaged by hail. The actual yields are given; the hail damage was estimated at 75 per cent.

³ Sorghum instead of rye was turned under in 1906.

⁴ Canada field peas instead of cowpeas were plowed under in 1910.

In 1906 a yield of 36.59 bushels to the acre was obtained from a plat of Burt spring oats (C. I. No. 293) on fall plowing, while 25 plats of this variety on spring plowing in tests conducted by the Office of Dry-Land Agriculture averaged only 13.33 bushels. This evidence is very strongly in favor of fall plowing for spring oats, but it is unlikely that such a large difference in yield would ordinarily be obtained.

ENVIRONMENTAL EXPERIMENTS.

In order to test the difference in yield between home-grown seed and seed grown in some other part of the country, the experiment reported in Table XXXIII was conducted in 1906. This was before the regular environmental or trilocal experiment with the Red Rust-proof oat, reported in Table XXXIV, was inaugurated. In both these experiments, better yields were obtained from home-grown seed than from that grown elsewhere. These tests indicate that it is advisable to use acclimated or home-grown seed whenever it is possible to obtain it.

TABLE XXXIII.—*Yields obtained in a source-of-seed test with spring oats at Amarillo, Tex., in 1906.*

C. I. No.	S. P. I. No.	Variety.	Source of seed.	Rate of seeding.	Yield per acre.
				Pecks.	Bushels.
165	¹ 5938	Sixty-Day	Channing, Tex.....	9	21.14
165	15857	.....do.....	McPherson, Kans.....	9	10.80
293	² 11145	Burt.....	Channing, Tex.....	9	16.02
293	16965	.....do.....	College Park, Md.....	9	11.40
293	15856	.....do.....	McPherson, Kans.....	10	³ 13.33

¹ The Sixty-Day oat (S. P. I. No. 5938) is the original seed from which S. P. I. No. 15857 was grown. The former had been grown at Channing, Tex., while the latter was grown at McPherson, Kans., during 1904 and 1905.

² The Burt oat (S. P. I. No. 11145) is the original seed from which the other two strains were grown. The Maryland and the Kansas seed were raised in those States, respectively, during 1904 and 1905, while the other was grown at Channing, Tex.

³ Average yield from 25 plats grown by the Office of Dry-Land Agriculture.

A trilocar environmental experiment with Red Rustproof oats, similar to the one already described with Crimean wheat,¹ was begun in 1908. Seed of this variety, grown by the Tennessee Agricultural Experiment Station at Knoxville, Tenn., was obtained and sent to Amarillo, Tex., and to the experiment station at Fayetteville, Ark., while a plat was also grown at Knoxville. Each year since, seed has been sent from the plat grown from the home-grown seed at each place to the other two points. The yields obtained in this experiment are presented in Table XXXIV. The rate of seeding in this experiment is 5 pecks to the acre. The plats have been sown on March 20, 1909, March 10, 1910, and March 23, 1911.

TABLE XXXIV.—*Annual and average yields obtained in the trilocar experiment with Red Rustproof spring oats at Amarillo, Tex., in 1909, 1910, and 1911.*

Source of seed.	Yield per acre (bushels).			
	1909	1910	1911	Average.
Amarillo, Tex. (home-grown seed).....	4.37	9.84	21.80	12.00
Knoxville, Tenn.....	2.81	8.13	18.44	9.79
Fayetteville, Ark.....	2.06	6.88	18.05	8.99

EXPERIMENTS WITH SPRING BARLEY.

VARIETAL TESTS.

Very little success has been attained in the tests of spring barley. Only one or two varieties have given results which are worthy of consideration. The Boehme Hooded (C. I. No. 507, beardless) has been grown more extensively than any of the others. It was used in the rotation and continuous-cropping plats of the Office of Dry-

¹ See p. 47.

Land Agriculture for several years, but failed to produce seed enough in 1910 for reseeding in 1911. A similar variety, the White Hooded (C. I. No. 716) was obtained and planted instead of the Boehme Hooded in 1911. The yields produced by these varieties are shown in Table XXXVI.

RATE-OF-SEEDING TEST.

The results of a rate-of-seeding test which was conducted with several varieties of spring barley in 1906 are presented in Table XXXV. These results are so variable that no definite conclusions can be drawn from them.

TABLE XXXV.—*Yields obtained in a rate-of-seeding test with spring barley at Amarillo, Tex., in 1906.*

C. I. No.	S. P. I. No.	Variety.	Rate of seed-ing.	Yield per acre.	C. I. No.	S. P. I. No.	Variety.	Rate of seed-ing.	Yield per acre.
			Pct.	Bush.				Pct.	Bush.
507	17525	Boehme Hooded...	4 6½ 7 9 11	4.79 6.08 6.30 7.14 7.02	236	9131	Hanna.....	4 6 6	3.43 3.48 1.82
					354	11192	Manchuria.....	4 6 6	1.82 3.28 1.77
					195	7999	Smyrna.....	4 6 6	1.77 0.88 0.88

SOIL-PREPARATION TESTS.

Table XXXVI shows the yields obtained with spring barley in 1907, 1908, 1909, and 1911 in experiments with different methods of soil preparation conducted by the Office of Dry-Land Agriculture.¹ The Boehme Hooded (C. I. No. 507) was used in 1907, 1908, and 1909 and the White Hooded (C. I. No. 716) in 1911.

TABLE XXXVI.—*Annual and average yields obtained in soil-preparation tests with spring barley at Amarillo, Tex., for the years 1907, 1908, 1909, and 1911.*²

Preparation and condition of the field.	Yield per acre (bushels).				
	1907	1908	1909	1911	Average.
Shallow spring plowing after barley.....	3.10	7.91	0	12.20	6.70
Deep fall plowing after barley.....	2.91	13.16	5.83	11.70	10.23
Clean-tilled summer fallow.....	5.00	15.20	17.50	15.00	15.90
Deep fall plowing and subsoiled after barley.....	2.70	11.87	0	10.30	7.39
Listed after barley and dragged level during summer.....	3.02	10.83	0	11.40	7.41
Disked and stubbled in after corn.....	2.50	7.50	0	11.80	6.43
Deep spring plowing after oats.....	2.29	8.13	0	12.30	6.81

¹ See footnote on p. 47.

² The 1910 crop is not included, as it was on new land which was all treated alike.

³ The 1907 crop is not included in the averages, as it was severely damaged by hail. The actual yields are given.

EXPERIMENTS WITH MISCELLANEOUS CEREALS.

PROSO.

Proso (*Panicum miliaceum*) is a species of millet introduced into this country from Russia. It is commonly called "hog millet" and "broom-corn millet" in the United States. It is grown for grain and not for hay. The grain is of value for feeding to live stock, particularly to hogs, sheep, and poultry. The characteristic of this grain that appeals most forcefully to the dry-land farmer is its ability to produce a crop of seed in two months or less from the time of seeding. There are several varieties of proso, the differences being mainly in the color of the seed and in the length of the straw. The seed may be white, yellow, red, or black. Some varieties have short and some have long straw, while the leaves are few in all. A black-seeded sort, the Black Voronezh (C. I. No. 27), has produced the best average yield in these tests, as shown in Table XXXVII. For the three years in which it has been grown the Yellow (C. I. No. 124) has yielded slightly more than any other variety. The yields in this table are based on a weight of 50 pounds to the bushel.

TABLE XXXVII.—Annual and average yields obtained in a varietal test with proso at Amarillo, Tex., for the five years from 1907 to 1911, inclusive.

C. I. No.	Variety.	Yield of grain per acre (bushels).					
		1907	1908	1909	1910	1911	Average.
27	Black Voronezh.....	9.25	19.50	4.14	12.20	16.85	12.39
43	White.....	5.20	17.40	.04	11.75	20.20	10.91
39	do.....	7.36	15.40	.00	12.25	18.45	10.69
125	Early Fortune.....		16.20	4.39	8.35	14.65	10.89
124	Yellow.....			2.19	12.35	19.50	11.34

FLAX.

Flax is a crop that is attracting much attention in the Panhandle region, though very little has been grown. A farmer living about 9 miles northeast of Amarillo reports an average yield of 15 bushels per acre on 250 acres, and 22 bushels per acre on 11 acres planted somewhat later. This statement has been widely circulated and many inquiries have been received at the station regarding the growing of flax. This crop has been tested in short rows, but not in field plats, except that some plats were seeded in 1911 on which the germination was very poor. The thin stand obtained permitted the weeds to grow and they soon choked the flax. Experiments with this crop will be continued on a larger scale.

BUCKWHEAT.

Very little has been done with buckwheat at Amarillo. Four varieties sent out by the Office of Cereal Investigations were planted in the summer of 1909. They were planted late—July 22—and made a very poor growth. Some seed was matured, but the straw was so short that it was impossible to harvest the crop.

EXPERIMENTS WITH CORN.

VARIETAL TESTS.

A great many varieties of corn have been tested at this station. The seed was obtained from widely different sources, including several foreign countries as well as many of the States. Corn has proved to be one of the poorest grain crops for the Panhandle country. It is much poorer than is indicated by the average yields. Sometimes,



FIG. 11.—View of a portion of the grain-sorghum, corn, and forage-sorghum plats at the Amarillo Cereal Field Station, Amarillo, Tex., in October, 1906.

when the crop has yielded well, the corn has been so badly worm-eaten that it was of little value. It was not a safe feed for any live stock except hogs, on account of the worm dust. The low yields have been due to drought, cool nights, and the attacks of various insects. Corn is not recommended as a crop for the Texas Panhandle, as other crops, particularly the grain sorghums, can be grown much more successfully. The poor growth of corn, as compared with the grain and forage sorghums, is shown in figure 11, though the crop of corn here shown, that of 1906, was one of the best produced at Amarillo.

Table XXXVIII gives the results of the varietal tests with corn. The varieties are grouped according to the number of years they have been grown, and are placed in each group in the order of their yields. It will be noted that less than half of the varieties which have been tested were still grown in 1911. Many of those remaining will be discarded later.

TABLE XXXVIII.—*Annual and average yields obtained in a test of varieties of corn at Amarillo, Tex., for the six years from 1906 to 1911, inclusive.*

C. I. No.	Name.	Kind of grain.	Source.	Yield of grain per acre (bushels).						
				1906	1907	1908	1909	1910	1911	Average.
110	Turney's June.....	White dent...	Channing, Tex.....	45.42	15.28	0	0.54	3.96	5.71	11.81
	Squaw.....	Purple flint...	Dalhart, Tex.....	22.80	6.57	0	1.07	18.57	2.71	8.62
	Channing Red.....	Red dent...	Channing, Tex.....	9.42	14.17	12.85	2.49	7.80	4.00	8.45
	Golden Beauty.....	Yellow dent...	Kansas.....	13.71	9.00	7.28	.23	5.35	4.85	6.73
	Eubank's Yellow.....	do.....	Channing, Tex.....	10.15	10.14	.45	10.42	6.42	7.51	7.51
129	United States Se- lection No. 133.	do.....	Corn Investigations...	5.07	18.94	.50	3.85	7.85	7.24	7.24
	Purple Dent.....	Purple dent...	New Mexico.....	10.71	0	.35	15.00	4.42	6.09	6.09
	Eldridge Red.....	Red flint...	Channing, Tex.....	13.32	0	2.39	7.67	5.57	5.79	5.79
	Jaune.....	Yellow flint...	Argentina.....	11.78	0	1.07	11.25	4.00	5.62	5.62
	Algerian.....	do.....	France.....	10.95	0	0	4.46	5.14	4.11	4.11
58	Andalusian.....	do.....	Spain.....	9.99	0	1.42	3.92	4.14	3.89	3.89
52	Yellow.....	do.....	China.....	5.71	0	.35	2.68	1.14	1.98	1.98
133	Moqui Black.....	Black flint...	Tuba, Ariz.....	14.05	3.33	13.21	1.92	8.12	8.12	8.12
123	Mexican June.....	White dent...	Hugoton, Kans.....	16.71	2.50	4.64	3.42	6.82	6.82	6.82
149	Yellow.....	Yellow flint...	do.....	.35	11.42	5.00	5.59	4.85	4.85	4.85
	Cooke's Prolific.....	White dent...	West Raleigh, N. C.....	.42	9.28	8.71	4.50	4.22	4.22	4.22
	Golden Glow.....	Yellow dent...	Madison, Wis.....	1.42	3.39	8.71	4.50	4.22	4.22	4.22
	Munson.....	White dent...	Sherman, Tex.....	.71	10.53	1.42	4.22	4.14	4.14	4.14
	Yellow Dent.....	Yellow dent...	Ulysses, Kans.....	0	2.85	9.57	4.14	3.72	3.72	3.72
144	Reid's Yellow Dent.....	do.....	Ames, Iowa.....	.47	6.07	4.64	3.48	3.48	3.48	3.48
143	Pittman.....	White dent...	Amarillo, Tex.....	1.42	7.14	2.42	3.66	3.00	3.00	3.00
	Texola June.....	do.....	Sherman, Tex.....	1.42	4.19	4.85	3.48	3.00	3.00	3.00
	Hadley's Yellow Dent.....	Yellow dent...	Coldwater, Kans.....	1.19	5.71	3.00	3.48	3.00	3.00	3.00
	Iowa Silvermine.....	White dent...	Ames, Iowa.....	.71	4.82	2.28	2.60	2.20	2.20	2.20
	Ferguson's Laguna.....	do.....	Sherman, Tex.....	1.42	2.49	2.71	1.49	1.49	1.49	1.49
69	Ferguson's Gourd Seed.....	do.....	do.....	1.42	2.85	.21	1.31	1.31	1.31	1.31
	Rice Pop.....	Pop.....	Amarillo, Tex.....				3.39	.85	2.12	2.12
	Stowell's Evergreen.....	Sweet.....	Corn Investigations...				2.34	.28	1.31	1.31
	Queen June.....	White dent...	Channing, Tex.....	27.14	13.80	5.71	0			
	Strawberry.....	Strawberry dent.....	do.....	21.48	7.49	0				
69	Marlboro's Prolific.....	White dent...	Bennettsville, S. C.....	13.14	6.98	0				
	McAulay's Prolific.....	do.....	Corn Investigations...	12.85	4.83	0				
	Laidigh's Yellow.....	Yellow dent...	Hutchinson, Kans.....	19.86	3.57	0				
	Laidigh's White.....	White dent...	do.....	11.60	5.00					
	Throckmorton's June.....	do.....	Channing, Tex.....	25.71						
125	Yellow.....	Yellow.....	Italy.....	20.71						
	Yellow Flint.....	Yellow flint...	do.....	14.28						
	Alexander's White.....	White dent...	Channing, Tex.....	14.28						
	Lela Red No. 1.....	Red dent...	Lela, Tex.....	11.42						
	Mexican June.....	do.....	do.....	10.71						
128	Mexican Red.....	do.....	do.....	9.42						
	Lela Red No. 2.....	Red dent...	Lela, Tex.....	9.42						
	United States Se- lection No. 120.	White dent...	Corn Investigations...	9.42						
	Hildreth's Yellow.....	Yellow dent...	Altamont, Kans.....	8.71						
	United States Se- lection No. 99.	White dent...	Corn Investigations...	8.00						
127	Eubank's Red.....	Red dent...	Channing, Tex.....	6.42						
	Coon's Yellow Dent.....	Yellow dent...	Dalhart, Tex.....	6.42						
	Laguna.....	White dent...	Galveston, Tex.....	14.04	0	.71	1.60			
	do.....	do.....	Corn Investigations...	16.19	4.06	0				
	Yellow Dent.....	Yellow dent...	Scott, Kans.....	8.57	0	0				
124	Eubank's June.....	White dent...	do.....	24.11						
89	Yellow Dent.....	Yellow dent...	Monon, Colo.....	10.71						
131	Red Flint.....	Red flint...	Hugoton, Kans.....	7.50						
	Mexican June X Yellow Dent.....	Red flint...	Madagascar.....	6.42						
	do.....	Yellow dent...	New Mexico.....	5.71						
	Moqui White.....	White flint...	Tuba, Ariz.....		15.08	3.21	3.39			
	Moqui Red.....	Red flint...	do.....		13.14	1.19	3.03			
114	Mexican Black.....	Black dent...	do.....		4.37	.71	.71			
147	White Flint.....	White flint...	Hungary.....							
146	Eight-Row Flint.....	do.....	Ames, Iowa.....		0					
145	Northwestern Dent.....	Yellow dent...	Rosser, Manitoba.....		0					
	Chisholm.....	White dent...	Sherman, Tex.....			2.14	4.28			
	Surecopper.....	do.....	do.....			1.42	4.82			
	Boone County White.....	do.....	Ames, Iowa.....			1.42	3.92			
	Ferguson's Yellow Dent.....	Yellow dent...	Sherman, Tex.....			1.42	2.85			

TABLE XXXVIII.—*Annual and average yields obtained in a test of varieties of corn at Amarillo, Tex., for the six years from 1906 to 1911, inclusive—Continued.*

C. I. No.	Name.	Kind of grain.	Source.	Yield of grain per acre (bushels).						
				1906	1907	1908	1909	1910	1911	Average.
152	Golden Dent.....	Yellow dent ..	Fargo, N. Dak.....				1.42	1.67		
142	Legal Tender.....	do.....	Emerson, Iowa.....				.71			
141	Silvermine.....	White dent.....	McLoud, Okla.....				0	1.26		
	Popcorn.....	White pop.....	Amarillo, Tex.....				.14	.73		
150	Silver King.....	White flint.....	Madison, Wis.....				1.07			
148	Smith's Ninety-Day	Yellow dent.....	Ames, Iowa.....				.71	6.07		
	Country Gentleman.	Sweet.....	Corn Investigations..					.28		
	Streeter's Hybrid...	do.....	do.....					.04		

The largest yield for the 6-year period from 1906 to 1911, inclusive, was obtained from a local variety known as Turney's June, while two other local varieties ranked second and third. The superiority of Turney's June is due entirely to the very large yield of 45.42 bushels to the acre produced by this variety in 1906. When this year is excluded from the averages, the Channing Red, another local variety, ranks first with an average yield of 8.26 bushels to the acre, followed by Eubank's Yellow, Squaw, United States Selection No. 133, and Turney's June, in the order named.

The highest yield for the three years 1909 to 1911, in which a number of commercial varieties from other States have been grown, was produced by the Squaw, a purple flint variety, from seed obtained in the Panhandle. This variety produced an average yield of 7.45 bushels to the acre. For this period, the other leading varieties, with the acre yield of each, were as follows: Purple Dent, 6.59 bushels; Moqui Black, 6.15 bushels; Eubank's Yellow, 5.76 bushels; Yellow Flint, 5.59 bushels; "Jaune," a yellow flint variety from Argentina, 5.44 bushels; and Eldridge Red, 5.21 bushels. Of these six varieties, four are of the flint type.

These investigations indicate that varieties of corn which have been grown in the locality for a number of years may usually be expected to give better yields than those obtained from a distance, even though much attention has been devoted to the improvement of these latter varieties in the regions from which they come. There does not seem to be any marked difference in yield between the flint and dent types, though the latter is probably to be preferred because it is more easily masticated by live stock. In a region such as this, where all grains are usually very hard in texture, this is an important consideration. As already stated, however, the grain sorghums are such well-adapted and profitable substitutes that there seems to be no good reason why corn should be extensively grown in the Texas Panhandle.

In addition to the varietal test which is reported in Table XXXVIII, an experiment with corn, United States Selection No. 133, is being conducted under the direction of Mr. C. P. Hartley, Physiologist in Charge of Corn Investigations. In this experiment, which has been in progress since 1907, the object is to study the behavior of corn when planted year after year with no selection whatever. Some work with corn varieties was also begun in cooperation with the Office of Corn Investigations in 1911.

DATE-OF-PLANTING TESTS.

The date-of-planting tests with corn have not been very extensive. The results are shown in Table XXXIX.

TABLE XXXIX.—*Yields obtained in date-of-planting tests with corn at Amarillo, Tex.*

Bloody Butcher, a red dent variety.			Eubank's June variety.	
Date of planting.	Distance between stalks.	Yield per acre.	Date of planting.	Yield per acre.
	<i>Inches.</i>	<i>Bushels.</i>		<i>Bushels.</i>
April 25, 1908.....	18 by 42	23.00	May 23, 1906	45.42
May 15, 1908.....	18 by 42	26.00	June 5, 1906	24.57
April 24, 1908.....	24 by 42	7.34	May 5, 1907	12.00
May 15, 1909.....	24 by 42	2.31	May 13, 1907	13.57
April 25, 1910.....	24 by 42	2.85	May 20, 1907	19.85
May 7, 1910.....	24 by 42	7.14	May 27, 1907	15.42
May 17, 1910.....	24 by 42	9.42	.....	.....

The Bloody Butcher variety reported in Table XXXIX is a red dent corn obtained in the locality, which is similar to the Channing Red and the Eldridge Red used in the varietal test. In 1908 and 1910 the later planting gave the higher yield, while the reverse was the case in 1909. The best yields of June corn (Table XXXIX) were obtained in 1906 and also in 1907 from plantings made about May 20. While the data presented are not conclusive, and variation is necessary from year to year according to climatic conditions, it is probable that better results are ordinarily to be obtained in the Pan-handle from corn planted about May 15 than from that planted at an earlier date.

RATE-OF-PLANTING TESTS.

In the experiments with corn at Amarillo, planting has generally been rather thick and the plants afterwards thinned to the desired stand. The rows were from 3½ feet to 3 feet 8 inches apart, with the plants 2 feet apart in the row. In years when the rainfall was abundant this stand is about right, but in years of drought a much greater distance between the plants is required. In 1907 a test was made of different distances between the stalks on plats of Eldridge

Red corn after wheat and after sorghum. The rows were 44 inches apart in all cases. From the plats which were grown after wheat a yield of 8.28 bushels to the acre was obtained where the stalks were 52 inches apart in the row, while 7.42 bushels were produced where they were 46 inches apart. Similarly, on the plats after sorghum the yields were 5.99 and 4.42 bushels, respectively, for row spacings of 49 and 44 inches. In both cases the larger yield was obtained from the thinner planting.

SOIL-PREPARATION TESTS.

Experiments with different methods of planting and cultivating corn were begun in 1906. In tests of sod land broken the previous fall surface-planted corn on spring plowing which was cultivated twice yielded 7.42 bushels to the acre and that cultivated five times yielded 8.57 bushels. Corn which was listed after spring plowing yielded 5.85 bushels when cultivated twice, and the same yield was obtained when it was cultivated five times. These results (Table XL) were obtained in experiments conducted by the Office of Dry-land Agriculture.¹ On sod broken the previous summer and backset in September, surface planting yielded 13.21 bushels, shallow listing 11.14 bushels, and deep listing 11.67 bushels. The last-named results are all average yields from two plats each, all of which were cultivated five times. These experiments indicate that surface planting is to be preferred to listing, while little is to be gained in this region by cultivating more than twice, unless it is necessary to prevent the formation of a crust on the soil. The common red dent variety was used in this experiment.

TABLE XL.--*Annual and average yields obtained in soil-preparation tests with corn at Amarillo, Tex., for the years 1908, 1909, and 1911.*²

Preparation and condition of the field.	Yield per acre (bushels).			
	1908	1909	1911	Average.
Shallow spring plowing after corn.....	20.28	0.57	8.10	9.65
Deep fall plowing after corn.....	22.85	2.71	* 9.20	11.58
Clean-tilled summer fallow.....	27.57	6.42	9.30	14.43
Deep fall plowing and subsoiled after corn.....	25.71	1.71	* 7.10	11.51
Listed in spring after corn, ordinary cultivation.....	25.28	7.28	7.60	13.38
Listed in spring after corn, good cultivation to conserve moisture.....	24.14	3.35	7.90	11.79
Deep fall plowing after oats.....	18.36	(³)	9.80	9.38
Deep spring plowing after oats.....	12.85	(³)	10.30	7.71
Deep fall plowing after winter wheat.....	23.11	(³)	7.36	10.16
Deep spring plowing after spring wheat.....	14.28	(³)	9.20	7.82
Deep fall plowing after spring wheat.....	18.95	(³)	9.00	9.31
Deep spring plowing after barley.....	17.00	(³)	9.00	8.66

¹ See footnote on p. 47.

² The 1910 crop is not included, as it was grown on new land.

³ Deep spring plowing, as the soil was too dry to plow the previous fall.

⁴ These plats were not husked, though all were better in yield of fodder than the poorly plowed, subsoiled, or fall-plowed plats for which yields are reported.

EXPERIMENTS WITH GRAIN SORGHUMS.

The grain sorghums are very well adapted to the Panhandle country and are the most dependable crops that can be grown. The growing of these feed crops will make stock farming, an occupation for which the Panhandle is admirably adapted, a most important industry. A great deal of work has been done with grain sorghums at Amarillo, more perhaps than with any of the other grains. These experiments were under the direction of Mr. Carleton R. Ball, Agronomist in Charge of Grain-Sorghum Investigations, and the data are in his possession. These data have been drawn upon by Mr. Ball in a number of bulletins.¹ To illustrate how these data have been used, the following quotation from one of these publications is given.²

The results of four years' experiments at the Amarillo Experiment Farm, Amarillo, Tex., indicate that in general the kaoliangs yield best with a stand of 1 stalk in each 5 or 6 inches of row; the milos and durras with 1 stalk in each 7 or 8 inches of row; and the kafirs with 1 stalk to each 9 or 10 inches of row. In all cases the rows are 3½ feet apart, and as far as possible the seeds are dropped singly in the rows. Under these conditions improved varieties in each of the three distinct groups give approximately the same yields. The Amarillo Experiment Farm has an elevation of 3,600 feet and an average rainfall of 22 inches, the larger part of which comes during the growing season. Further investigations, continuing the experiments through a longer period of years, may discover that better average yields will be produced at other spacings than those noted above.

VARIETAL TESTS.

The different phases of the grain-sorghum experiments are not discussed in detail here, as a bulletin covering this work is in preparation. In Table XLI the annual and average yields of the varieties grown in field plats from 1906 to 1911, inclusive, are given. These averages include the poor plats each year as well as the good ones. For this reason the yields here reported are approximately those that can be expected from the ordinary methods of farming.

¹ Farmers' Bulletin 322, Milo as a Dry-Land Grain Crop, 1908; Farmers' Bulletin 448, Better Grain-Sorghum Crops, 1911; Bulletin 175, Bureau of Plant Industry, The History and Distribution of Sorghum, 1910; Bulletin 203, Bureau of Plant Industry, The Importance and Improvement of the Grain Sorghums, 1911; and Bulletin 253, Bureau of Plant Industry, The Kaoliangs: A New Group of Grain Sorghums, 1913.

² Farmers' Bulletin 448, Better Grain-Sorghum Crops, p. 29. 1911.

TABLE XLI.—*Annual and average yields of grain-sorghum varieties at Amarillo, Tex., for the six years from 1906 to 1911, inclusive.*¹

Variety.	Yield per acre (bushels).						
	1906	1907	1908	1909	1910	1911	Average.
Milo.....		23.93	35.62	6.14	19.67	32.28	23.52
Dwarf milo.....			41.37	11.00	20.68	38.24	27.82
White milo.....					14.73	31.51	23.12
White durra.....			33.29	11.51	10.60	32.44	21.96
Buff durra.....			33.88	8.80	7.22	22.32	18.06
Durra-kafir hybrids.....			35.07	4.23	12.35	29.93	20.39
Blackhull kafir.....	44.36	18.91	33.82	5.04	9.66	21.24	22.17
Red kafir.....	42.85		33.06	3.81	5.21	18.68	20.72
White kafir.....				8.67	9.46	25.01	14.38
New African kafirs.....				5.37	4.61	24.42	11.46
Blackhull kaoliang.....			43.10	9.44	6.92	25.40	21.21
Brown kaoliang.....			29.71	13.04	10.45	22.09	18.82
White kaoliang.....			18.10	14.27	10.72	25.40	17.12
Shallu.....	26.10		(²)		.40	17.20	14.57
Milo hybrids.....					9.60	22.00	15.80

¹ In this table, the average for each crop is taken from all the plats of that crop grown at the farm that year, regardless of the special tests in which they were included. In a number of cases this greatly reduced the average yield. For example, the brown kaoliangs included a large number of different strains, some of which were very low yielders. The table, however, gives a general idea of what these crops will do under ordinary conditions.

² The crop of shallu for 1908 lodged very badly before ripening and was not harvested. The estimated yield was 15 bushels, but this is not used in the table. In 1909 no shallu was planted.

Only one variety, the Blackhull kafir, has been grown continuously during the six-year period from 1906 to 1911. The average yield of all tests of this variety is 22.17 bushels to the acre, as compared with 11.81 bushels of Turney's June, the leading variety of corn in the varietal test. For the five years from 1907 to 1911, milo has produced an average yield of 23.52 bushels, Blackhull kafir 17.73 bushels, and Channing Red, the leading variety of corn for this period, only 8.26 bushels. A number of varieties have been grown for the four years from 1908 to 1911, inclusive. For this period the best average yield was produced by Dwarf milo, 27.82 bushels, followed by ordinary milo with 23.43 bushels, white durra with 21.96 bushels, and Blackhull kaoliang with 21.21 bushels. The leading variety of corn yielded only 7.45 bushels to the acre for the same period. At present, milo and kafir are most generally to be recommended for the Panhandle region. Part of a row of Dwarf milo in the breeding plat at Amarillo is shown in figure 12.

SOIL-PREPARATION TESTS.

In Table XLII the results obtained in the soil-preparation experiments for milo and kafir conducted by the Office of Dry-Land Agriculture are presented.¹ In 1907, standard milo (C. I. No. 235), was used in this test; in 1908, Dwarf milo (C. I. No. 236); and in 1909 and 1911, standard milo (C. I. No. 234). Blackhull kafir has been used in all the experiments with that crop.

¹ See footnote on p. 47.

TABLE XLII.—*Annual and average yields obtained in soil-preparation tests with milo and kafir at Amarillo, Tex., in 1907, 1908, 1909, and 1911.*¹

Preparation and condition of the field.	Yield per acre (bushels).				
	1907	1908	1909	1911	Average.
Preparation for milo:					
Shallow spring plowing after milo	18.73	41.78	2.7	35.3	24.96
Deep fall plowing after milo	22.32	33.92	1.0	² 31.4	22.54
Listed in spring after milo and planted at once	32.85	39.28	11.1	17.4	22.77
Deep fall plowing after winter wheat	28.87	48.12	10.4	26.4	28.39
Preparation for kafir:					
Shallow spring plowing after kafir	11.42	29.66	2.2	22.4	14.11
Deep fall plowing after kafir	14.28	31.35	1.6	² 22.4	17.52
Listed in spring after kafir and planted at once	12.67	27.62	5.7	8.3	13.39
Deep fall plowing after winter wheat	17.85	38.97	4.8	19.6	19.96

¹ The 1910 crop is not included, as it was grown on new land.² Deep spring plowing, as the land was too dry to plow in the fall.

FIG. 12.—Portion of a head row of Dwarf milo in the breeding experiments at the Amarillo Cereal Field Station, Amarillo, Tex.

EXPERIMENTS WITH BROOM CORN.

Broom corn is another sorghum which is adapted to the Panhandle country and which promises to be one of the money crops. It is already grown to some extent, but is not a regular crop. Individual farmers try it for a year or so and then give it up because of a poor crop or low prices or because they find they do not understand how to

handle it. There are a few men, however, who grow broom corn regularly and who seem to find the crop a profitable one.

Aside from the breeding of a dwarf strain of standard broom corn, very little work has yet been done with this crop at the Amarillo station. A few rows have been grown each year for several years and head selections have been made and studied. More extensive work is now in progress, but no data as to yields are yet available. The growth, cultivation, and general care of broom corn in the field are very similar to that of the other sorghums. The harvesting, curing, baling, and storing of the brush, on the other hand, are problems altogether different from those met with in the growing of either grain sorghums or forage sorghums.

CEREAL-DISEASE EXPERIMENTS.

Much cereal-disease work of the Office of Cereal Investigations has been done at the Amarillo station, and the field investigations of the diseases of sorghum have been concentrated there since 1907, 10 to 30 tenth-acre plats having been used each year. Other diseases which have been studied include the loose smuts of wheat and barley, the stinking smut of wheat, covered smut of barley, and oat smut.

THE SORGHUM SMUTS.

The life history of the kernel smut of sorghum (*Sphacelotheca sorghi* (Link.) Clint.), has been investigated for this region. This smut lives from year to year as spores, which get on the seed in thrashing and handling. When such smutted seed is planted, the smut again occurs in the crop. All varieties of sorghum, with the exception of milo, are subject to the attack of this disease. The life history of the head smut of sorghum (*Sphacelotheca reiliana* (Kuhn) Clint.), heretofore unknown, has been worked out and will be described in a forthcoming bulletin. A third smut (*Ustilago cruenta* Kuhn), very similar to kernel smut, has recently been found at Amarillo. In 1911 it was shown that it lives from year to year exactly as does the kernel smut.

A very satisfactory treatment for the prevention of kernel smut has been tested at Amarillo. This consists in soaking the seed in a solution of 1 pound of formalin to 30 gallons of water for 1 hour. The seed can be sown immediately after treatment or, if dried carefully, can be kept for weeks or months without injury to the germination. This treatment is also effective for the new kernel smut.

A large number of treatments have been tried for the head smut, but none has yet been found effective. The only way now known to reduce this smut is to remove all smutted plants as they appear and to burn them so as to destroy all the spores, but it is hoped, from recently acquired knowledge of its life history, that specific preventive

measures may be developed. Circular No. 8 of the Bureau of Plant Industry on the smuts of sorghum has been published as a result of the work done at Amarillo. This circular describes both the kernel smut and the head smut and discusses various methods for their prevention.

THE LOOSE SMUTS OF WHEAT AND BARLEY.

Considerable field work has been done on the loose smuts of wheat and barley. These smuts have been very abundant in some varieties of these grains at this station. A large number of varieties have been treated with the modified hot-water treatment. This consists of soaking the seed in cold water for 5 hours and then treating it in hot water at 54° C. for 10 minutes for wheat or at 52° C. for 15 minutes for barley. This treatment was found to be effective in preventing the loose smuts. These smuts, with the treatments for their control, are fully described by Freeman and Johnson in Bulletin No. 152 of the Bureau of Plant Industry.

THE STINKING SMUT OF WHEAT, SMUT OF OATS, AND COVERED SMUT OF BARLEY.

Little experimental work has been done on stinking smut of wheat, oat smut, and covered smut of barley at Amarillo. These smuts, however, have been found in many of the varieties. In order to prevent them, the seed has been treated with a formaldehyde solution composed of 1 pound of 40 per cent formaldehyde (formalin) to 40 gallons of water. This treatment is very effective and is now applied every year to all of the varieties in the field plats in order to keep the station free from these smuts.

EXPERIMENTS WITH FORAGE CROPS.

Various experiments with forage crops have been conducted cooperatively at the Amarillo field station by the Office of Forage-Crop Investigations since the farm was established. Two publications have been prepared by the Office of Forage-Crop Investigations, containing in part the data resulting from these experiments. These are Bulletin 102 of the Texas Agricultural Experiment Station, entitled "Forage Crops for Northwest Texas," and Farmers' Bulletin 458 of the United States Department of Agriculture, entitled "The Best Two Sweet Sorghums for Forage."

EXPERIMENTS WITH MISCELLANEOUS CROPS.

SUGAR BEETS.

The experiments with sugar beets at the Amarillo station were conducted in cooperation with and under the direction of Dr. C. O. Townsend, formerly pathologist in charge of sugar-beet investigations

of the Bureau of Plant Industry. The detailed results are now on file in that office. A number of experiments were conducted in 1907. In 1908 no stand was secured, though two plantings were made. In 1909, 20 twentieth-acre plats were grown with a different variety on each plat. No attempt is made here to give the details of these experiments. Table XLIII gives briefly the average results for the two years the sugar beets were grown. The highest yield, the highest percentage of sugar in juice, and the highest coefficient of purity are also given for each year. The highest results in the three columns were not obtained on the same plats. The highest yield was obtained on one plat, the highest percentage of sugar in juice from another, and the highest coefficient of purity from a still different plat.

TABLE XLIII.— *Yield, sugar content, and coefficient of purity obtained in tests of sugar beets at Amarillo, Tex., in 1907 and 1909.*

Statement of averages.	Yield per acre.	Sugar content in juice.	Coefficient of purity.
	<i>Pounds.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Average for 1907.....	12,365	17.81	82.34
Average for 1909.....	5,414	16.67	78.86
Average for two years.....	8,889	17.24	80.60
Highest for 1907.....	20,620	22.40	88.90
Highest for 1909.....	8,780	18.40	84.00

COTTON.

A great many questions about the cotton crop are asked by people looking for investment or homes in the Panhandle country. Cotton is not grown commercially nearer than 100 miles to the south and east of Amarillo. Very little experimenting has been done with cotton, either at the station or by the farmers in this region. The office in charge of cotton investigations has not undertaken any work in the Panhandle, but two experiments have been made by the farm superintendent, one in 1909 and the other in 1911.

The seed for the first experiment was furnished by Mr. J. H. Avery, of Amarillo, Tex., who was then acting as secretary of the Amarillo Chamber of Commerce. This seed was at least two years old when planted. The notes are briefly as follows: Approximately a twentieth-acre plat was planted May 17, 1909, half of which was on fall-plowed wheat land and half on cowpea land, double disked in the spring. The soil was in good condition but rather dry. The cotton was seeded quite thickly in rows 2 feet apart. The plants appeared above the ground on May 31. When they reached a height of 6 or 8 inches they were thinned to one plant to every 10 or 12 inches of

row. Good level cultivation was given. The plants attained a height of 15 inches, with an estimated average of 15 bolls to the plant, most of which matured. The first picking was made on October 2. Other pickings were made at intervals during the month of October. A total of 17 pounds of seed cotton was picked from the plat. This is at the rate of 340 pounds of seed cotton per acre.

The seed for the second experiment was furnished by Mr. O. B. Burnett, of Memphis, Tex. It was from a strain of cotton he has been improving for a number of years. A tenth-acre plat was planted May 27 on spring-plowed cowpea land in rows $3\frac{1}{4}$ feet apart, coming up unevenly on June 7. It was not thinned, as the stand was thin enough, though rather uneven, averaging about 12 inches between plants in the row. Good cultivation was given. Squares began forming on July 22, and the first blossom appeared during the first week in August. The first boll opened on September 23, but the crop was not picked until December 11 and 12. The picking was done late in order to test the ability of the bolls to hold the lint. About 2 per cent (estimated) of the lint was blown out. The yield per plat was 65 pounds of seed cotton, or 650 pounds per acre.

Further testing will have to be done before it will be safe to draw any very definite conclusions in regard to the growing of cotton in this region. It is rather doubtful if it will ever make a successful crop here.

EXPERIMENTS AT DALHART.

In 1907 a farm and permanent equipment for experimental work at Dalhart, Tex., was placed at the disposal of the Office of Cereal Investigations. This farm finally was organized as one of the field stations of the Office of Dry-Land Agriculture. Dalhart is 81 miles northwest from Amarillo. Conditions at the two places are very similar, except that the soil at Dalhart is more sandy than that at Amarillo. The experiments with cereals have therefore been confined chiefly to varietal tests in order to determine varieties adapted to that soil type. The general results of these tests are herein given.

VARIETAL TESTS OF CEREALS.

The small-grain tests in 1908 were entirely destroyed by hail on June 15. The season was very dry, there being but 12.28 inches of rain during that year. The grain sorghums were also destroyed by hail. Some of the varietal plats were replanted later, but none matured. Six plats of milo grown in various tillage and rotation tests by the Office of Dry-Land Agriculture gave an average yield of 26.8 bushels to the acre, but the replanted kafir did not mature grain, though making good yields of fodder.

The year 1909 was a very severe one for all grains. Yields were obtained from winter wheats, winter rye, spring wheats, proso, and milo. Complete failures occurred in the case of winter barley, winter oats, and winter emmer. Most of the grain sorghums were planted too thickly and did not survive the extreme summer drought. Two plats of milo, which were more favorably located to accumulate spring run-off water than the remainder of the plats, gave an average yield of 26 bushels to the acre.

In 1910 the variety tests of small grains were entirely destroyed by the blowing and drifting of the soil. The grain-sorghum varieties made an excellent crop.

WINTER SMALL GRAINS IN 1909.

The winter small grains harvested in 1909 were planted on land broken from sod in August, 1907, fallowed in 1908, and plowed 6 inches deep in August of that year. Practically no rain fell in August, September, October, and November, 1908. The seeding was done on November 24, having been delayed on account of the dry weather. There was snow equaling 0.93 inch of precipitation on November 27. Much of the grain germinated but made no appreciable growth before winter. The yields obtained from the varieties of wheat and rye are shown in Table XLIV.

TABLE XLIV.—Yields of straw and grain obtained from varieties of winter wheat and rye at Dalhart, Tex., in 1909.

C. I. No.	S. P. I. No.	Name.	Original source.	Yield per acre.		Weight per bushel.
				Straw.	Grain.	
		WINTER WHEAT.		<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
1558	11610	Turkey.....	Russia.....	1,990	16.83	60
1561	5498	Theiss.....	Austria.....	1,840	16.83	60
1559		Crimean.....	Hungary.....	1,820	16.33	58
2902		Mammoth Red.....	Oklahoma.....	1,630	15.33	60
2943		Hard red winter.....	Local.....	1,450	12.50	59
2223	11229	Turkey.....	Russia.....	1,290	11.83	60
1543	6012	Belogilna.....	do.....	1,700	11.67	59
1437	5636	Crimean.....	do.....	1,600	11.67	57
1563	5499	Weissenberg.....	Austria-Hungary.....	1,750	11.67	58
1560	5496	Banat.....	do.....	1,550	11.67	60
1562	5498	Bacaka.....	do.....	1,530	11.67	58
1667	7787	Belogilna.....	Russia.....	1,460	11.50	59
2206	9125	Kharkof.....	do.....	1,940	11.00	59
1442	5641	Do.....	do.....	1,480	10.33	58
1436	5635	Crimean.....	do.....	1,310	9.83	57
1438	5637	Ghirka.....	do.....	1,490	9.33	59
2339	9358	Belogilna.....	do.....	1,200	9.16	59
1435	6015	Crimean.....	do.....	1,160	8.16	58
2398	9872	Galgalos.....	do.....	850	7.50	58
2942	17994	Rieti.....	Italy.....	850	6.66	59
1571		Turkey.....	Kansas ¹	1,750	5.00	60
2092	7430	Jejar.....	Spain.....	900	4.17	56
1395-2		Diehl Mediterranean.....			3.33	56
		WINTER RYE.				
114		Kansas.....	Kansas.....	1,850	5.36	55
34	10367	Ivanov.....	Russia.....	1,600	5.36	55

¹ Originally from Kansas, but the seed used for this crop had been grown for several years previously in British Columbia.

SPRING SMALL GRAINS IN 1909.

Twenty-seven varieties of spring wheats were tested on tenth-acre plats in 1909. Most of these varieties failed by reason of a combination of drought and soil blowing. Since these failures were not wholly due to the varieties themselves, the varieties destroyed are not reported. Yields of the remainder are found in Table XLV. The yields obtained from five varieties of proso are also included.

TABLE XLV.—*Yields of straw and grain obtained in a varietal test of durum and common spring wheat and proso at Dalhart, Tex., in 1909.*

C. I. No.	S. P. I. No.	Name.	Original source.	Yield per acre.		Weight per bushel.
				Straw.	Grain.	
DURUM WHEAT.						
2246	10364	Kubanka.....	Russia.....	<i>Pounds.</i> 1,530	<i>Bushels.</i> 7.83	<i>Pounds.</i> 59
2575		Cavarna.....	Bulgaria.....	1,130	7.83	60
2537-1-1		Marchard.....	Algeria.....	1,100	6.67	58
2545-1		Semonlier.....	do.....	960	5.67	59
2689		.....	Italy.....	870	5.50	58
2692		Realforte.....	do.....	640	1.83	58
COMMON WHEAT.						
2398	9872	Galgales.....	Russia.....	1,950	14.17	58
PROSO.						
27	9425	Black Voronezh.....	.....	1,700	10.00	.....
	22422	.....	.....	700	5.00	.....
		Native.....	.....	1,200	3.91	.....
11	2797	Red Russian.....	.....	1,950	Failed.	.....
39		White.....	.....	1,950	do.....	.....

GRAIN SORGHUMS.

In 1909, 2½ acres were used for grain-sorghum tests. This land had been fall plowed in 1908 and given good care. Fourteen varieties were grown in a total of 23 tests of one-tenth acre each and 4 tests of one-twentieth acre each. Of these tests all failed but two one-tenth acre plats of milo (C. I. No. 235) and one one-tenth acre plat of Dwarf milo (C. I. No. 236). The two plats of milo averaged 26.5 bushels of grain per acre, while the single plat of Dwarf milo yielded at the rate of 25.4 bushels per acre. As previously noted these plats were so located as to receive a considerable amount of run-off water early in the season and thus had an advantage over the other plats.

RATE-OF-SEEDING TESTS WITH WHEAT.

The results of seeding both winter and spring wheat in 1909 at different rates are given in Table XLVI.

TABLE XLVI.—*Yields of straw and grain obtained in rate-of-seeding tests with winter and spring wheat at Dalhart, Tex., in 1909.*

Kind of wheat.	Rate of seeding.	Yield per acre.		Weight per bushel.
		Straw.	Grain.	
	<i>Pecks.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
Turkey winter.....	2	1,700	13.33	60
	3	1,990	16.83	60
	4	1,920	17.83	60
	5	1,940	18.50	60
	6	2,320	20.33	60
Kubanka durum spring.....	2	900	4.16	59
	3	1,390	6.16	59
	4	1,530	7.83	59
	5	1,970	10.50	59
	6	890	5.33	58
Galgalos common spring.....	3	1,480	13.67	58
	4	1,950	14.17	58
	5	920	7.83	.....

Owing to winter drought and spring winds the killing of both the winter and spring wheat was very severe. The thickest plantings in this test were not too thick this year, while ordinarily they would have been so thick as to have been partly stunted. For that reason the test is of little value as an indication of the proper rate of seeding.

EXPERIMENTS AT CHILLICOTHE.

Varietal tests of small grains have been conducted at Chillicothe, Tex., for five years. The tests at that place are made on an experiment farm operated cooperatively by the Office of Forage-Crop Investigations and the Texas Agricultural Experiment Station. The small grains grown there are but a minor part of the work of the Chillicothe station, which is primarily for the testing and improvement of forage crops. A general view of the small-grain tests at this station in 1906 is shown in figure 13.

LOCATION, RAINFALL, AND SOIL.

Chillicothe is about 150 miles southeast of Amarillo. Its altitude is 1,500 feet, which is 2,340 feet lower than that of Amarillo. While it lies somewhat beyond the eastern edge of what is defined as the Panhandle in this bulletin, the data obtained are applicable to the eastern and lower portions of the region and so supplement those obtained at Amarillo and elsewhere. Chillicothe is about at the western edge of the older wheat-growing section of the State and may be regarded as representative of quite a large territory along both sides of the Red River and of the districts with similar elevations to the north and south.

The average rainfall is approximately 23 inches per annum, although data are not obtainable for a sufficient period of years to

establish a final conclusion. The rainfall data for the years reported are given in Table XLVII.

TABLE XLVII.—*Monthly, annual, and average precipitation, in inches, at Chillicothe, Tex., for the five years from 1906 to 1910, inclusive.*¹

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906.....	0	0	0.90	3.92	1.78	4.20	8.71	2.67	5.02	4.58	Tr.	0	31.78
1907.....	0	0	3.42	.98	7.81	2.56	1.46	1.52	1.71	6.60	0.80	0	26.86
1908.....	Tr.	Tr.	.28	3.51	6.40	8.41	5.68	Tr.	2.22	1.84	4.13	Tr.	32.47
1909.....	0	0.22	1.89	1.41	.56	8.06	.49	1.07	.26	1.84	4.57	0	20.37
1910.....	.64	.08	1.08	1.39	2.74	1.91	1.42	1.74	1.22	1.30	.14	0.53	14.19
Average....	.13	.06	1.51	2.24	3.86	5.03	3.55	1.40	2.08	3.23	1.93	.10	25.13

¹ Furnished by A. B. Conner, Assistant Agrostologist, Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture, Chillicothe, Tex.

The soil on which the station is located is a rather sandy reddish loam which contains enough of a shale-like clay to bake after hard



FIG. 13.—General view of the plots of small grain at Chillicothe, Tex., in 1906, grown in cooperation with the Office of Forage-Crop Investigations.

rains. This soil washes somewhat and will drift badly in bare, level fields during high winds.

VARIETAL EXPERIMENTS WITH WINTER CEREALS.

The results of varietal trials of winter cereals obtained from 1906 to 1910, inclusive, are given in Table XLVIII. The land seeded in the fall of 1905 had produced a good crop of winter wheat. It was prepared just as the farmers in that locality prepare their fields. The land for the 1907 crop was in cowpeas in 1906. During the spring of 1907 the green bug or grain aphid destroyed about all the small grain in that part of the State. The fields at the station were infested, but drought and other weather conditions checked the development of the insects and a small crop of grain was obtained.

The 1908 crop was seeded in good condition on land cropped in cowpeas in 1907. An excellent crop was harvested, but most of the value of the year's work was lost because of a storm which mixed the shocked grain on part of the plots so as to render accurate yield

tests of each variety impossible. Careful notes had been made previously and it is thought that Mediterranean winter wheat (C. I. No. 1395-2) would have produced a yield of 20 bushels per acre. The mixed bundles were collected and when thrashed gave an acre yield of 14 bushels as the average of these plats.

The crop of 1909 was seeded on land which had been in cowpeas in 1908 and the prospects for a good crop were excellent. However, the winter was very severe and much winterkilling resulted from blowing soil.

The seeding in the fall of 1909 was done on cowpea land and a good stand was obtained, but the dry spring in 1910 resulted in a very small crop.

TABLE XLVIII.—*Annual and average yields obtained in varietal tests of winter grains at Chillicothe, Tex., 1906 to 1910, inclusive.*

C. I. No.	S. P. I. No.	Name.	Kind of grain.	Origin.	1906	1907	1908	1909	1910	Average.
WHEAT.										
2246	10364	Kubanka ¹	Durum	Russia	Bus. 23.80	Bus. 13.14	Bus. 19.50	Bus. 7.31	Bus. 1.50	Bus. 13.05
1564	12015	Pesterboden	Hard red	Hungary	20.40	7.06	9.50	8.79	2.66	9.68
1558	12013	Turkey	do	Russia	24.00	7.56		6.36	3.83	10.44
2208	9125	Kharkof	do	do	20.30	9.45		2.08	1.00	8.21
1561	12004	Theiss	do	Hungary	30.80	7.11		6.79		14.90
1563	11650	Weissenberg	do	do	19.50	5.76		7.38		10.88
2900-1		do	do	do	24.60				1.66	
1596	7582	Fretes	Medium red	Algeria	17.30				1.83	
1436	12007	Crimean	Hard red	Russia	22.60	8.16				
2398	9872	Galgas	Medium hard white	do	20.10	7.11				
1667	12002	Beloglina	Hard red	do	21.80					
2239	9358	do	do	do	20.10					
1395-2		Diehl Mediterranean	Medium hard red					8.05	4.83	
EMMER.										
2337	11650	Black Winter ¹		France	48.21	40.00	49.00	8.00	2.80	29.60
RYE.										
34	10367	Ivanov		Russia	19.10	12.56	15.53	4.87	1.16	10.64
40	10366				15.00					
BARLEY.										
257	11193	Tennessee Winter			Failure.					
SPELT.										
1772		Red Winter			Failure.					

¹ Tried as a winter durum. The seed was not pure and the common wheat in the mixture soon crowded out the durum. The latter gradually winterkilled until in 1910 there was none left in the crop.

² Average of two plats.

³ Figured at 25 pounds per bushel.

The largest yields of wheat in these tests were produced by varieties of the hard red or Turkey type. Turkey, Kharkof, and Theiss were among those which gave the best results. As noted in the table, the Kubanka (C. I. No. 2246), which is reported as giving the highest yield, was mixed with other varieties in the earlier years of the experiment, while the plat grown under this name contained none of this

variety in 1909 and 1910. Black Winter emmer (C. I. No. 2337) averaged 29.6 bushels (about 740 pounds) for the five years, while Ivanov rye yielded 10.64 bushels (about 600 pounds) for the same period.

SUMMARY.

The Panhandle of Texas was for many years occupied by great cattle ranches which in recent years have been offered for sale as farm lands. The need of the new settlers on such lands for information as to adapted crops and cropping methods has been and still remains very great.

Experiments designed to supply the needed information were begun by the Office of Cereal Investigations in 1903 and have been conducted without interruption since that date, first at Channing and then at Amarillo, Tex. Minor experiments have been conducted cooperatively with other offices of this bureau at Chillicothe and Dalhart, Tex.

The Panhandle includes about 47 counties in northwestern Texas. In general, it is a high, dry plain with an elevation of 2,000 to 4,000 feet. The average annual precipitation in different parts ranges from 18 to 23 inches, most of which falls during the summer months. It is a region of low humidity, high evaporation, high average wind velocity, abundant sunshine, and relatively cool nights.

The predominant soil type is a clay or clay loam with some sandy areas and some heavy clays or adobes. The grass covering on the clayey soils consists largely of buffalo grass and blue grama. On the sandier soils bluestems (*Andropogon* spp.) are especially prevalent.

EXPERIMENTS AT CHANNING, TEX.

Experiments were conducted at Channing, Hartley County, from the autumn of 1903 to the autumn of 1906 in cooperation with the Capitol Freehold Land & Investment Co. on their XIT ranch. The crop of 1904 was nearly a complete failure, owing to new land and a drought lasting until the end of April. Results obtained in 1905 and 1906 show that hard red winter wheats, black winter emmer, and winter rye gave profitable yields. Among spring wheats Galgalos and Chul (common) wheats and Kubanka (durum) wheat were the best-yielding varieties, but none of them equaled the winter varieties. Early oats like Burt, Red Rustproof, and Sixty-Day gave only fair yields and later varieties still smaller. No spring barleys did well.

The date-of-seeding and rate-of-seeding tests were of too short duration to yield conclusive results, as were also the tests of the comparative value of fallowing and continuous cropping.

In a test of many varieties of corn the average yield of the best variety in a three-year period was less than 40 per cent of the yield of milo.

Milo and kafir proved good yielders of grain, the three-year average yield of milo being 42 bushels of 56 pounds each.

EXPERIMENTS AT AMARILLO, TEX.

Experiments were begun at Amarillo in 1905 and transferred to the new farm at that place in 1909. Very extensive experiments, partly cooperative with other offices, have been conducted since the latter date.

Hard red winter wheats of the Turkey group and medium-hard sorts of the Mediterranean group have proved best adapted, giving yields of 7.5 to 10.5 bushels per acre for the six-year period ended in 1911. The best varieties of winter spelt and emmer have yielded 25 and 19.6 bushels, respectively, in the same period.

Tennessee Winter barley gave an average yield in the six-year period of 10.6 bushels, and the best winter rye 9 bushels, but no varieties of winter oats have proved sufficiently winter hardy.

Experiments in dates and rates of seeding of winter wheat show that 3 pecks per acre sown between October 15 and 30 gave the best average results. Cultural experiments indicate that best results will be obtained when the land is plowed at least 6 inches deep from 60 to 80 days before seeding. When the land can not be prepared until nearly seeding time disking has given better results than plowing.

Spring wheats have been somewhat lower in yield than winter wheats. The best varieties were the common wheats, Fretes and Galgalos, yielding 9.3 bushels on the average, and the durum wheats, Marouani, Saragolla, and Kubanka, yielding 8.7, 8.6, and 7.9 bushels per acre in the order named.

Experiments indicate that 4 pecks per acre for the common spring wheats and 5 pecks per acre for durum wheats are the best average rates of seeding, subject to variation with varying weather and soil conditions. The best date of seeding varies from the last of February to the middle of April, depending on conditions of weather and soil moisture.

The spring oat varieties, Red Algerian and Red Rustproof, have yielded 19.8 and 18 bushels, while different strains of Sixty-Day, Kherson, and Burt have varied between 13.6 and 17.8 bushels for the six years from 1906 to 1911. Results of rate-of-seeding tests have been contradictory, indicating that the proper rate is governed by weather and soil conditions. However, 5 pecks is probably the best rate for average conditions. Early or medium early seeding is usually to be recommended. Fall plowing for spring oats has been

found most desirable, and home-grown seed has given better results than seed of the same variety brought from a distance.

Spring barley has not given profitable yields, the best variety being the White Hooded, yielding from 5 to 7 bushels in the six-year average.

Proso (broom-corn millet) varieties have produced average yields of 10.7 to 13 bushels per acre in tests lasting from four to six years.

The results in tests of corn during the six-year period show it not to be adapted to the Panhandle country. The best variety, a June corn, yielded 11.8 bushels, and only three varieties exceeded 8 bushels per acre on an average during that time. Omitting the results of one season, a locally grown red dent has yielded slightly better than the June corn.

The grain sorghums are the most dependable crops that can be grown in the Panhandle. In the five years, 1907 to 1911, inclusive, the average yields of all varieties of milo were 23.5 bushels, while all varieties of dwarf milo in the last four years of this period yielded an average of 27.8 bushels. Blackhull and Red kafir made an average yield of 20 bushels in the six-year period, 1906 to 1911, excluding 1907 in the case of Red kafir. Varieties of durra and kaoliang also made good yields. About 3 pounds per acre is the proper rate of planting and the best date in the vicinity of Amarillo is about May 20, varying however, with the season.

Dwarf broom corn is suited to the region, but requires judgment and experience to make production profitable. It should be grown only by farmers who expect to continue growing it for a period of years and who can afford the necessary equipment to handle it properly.

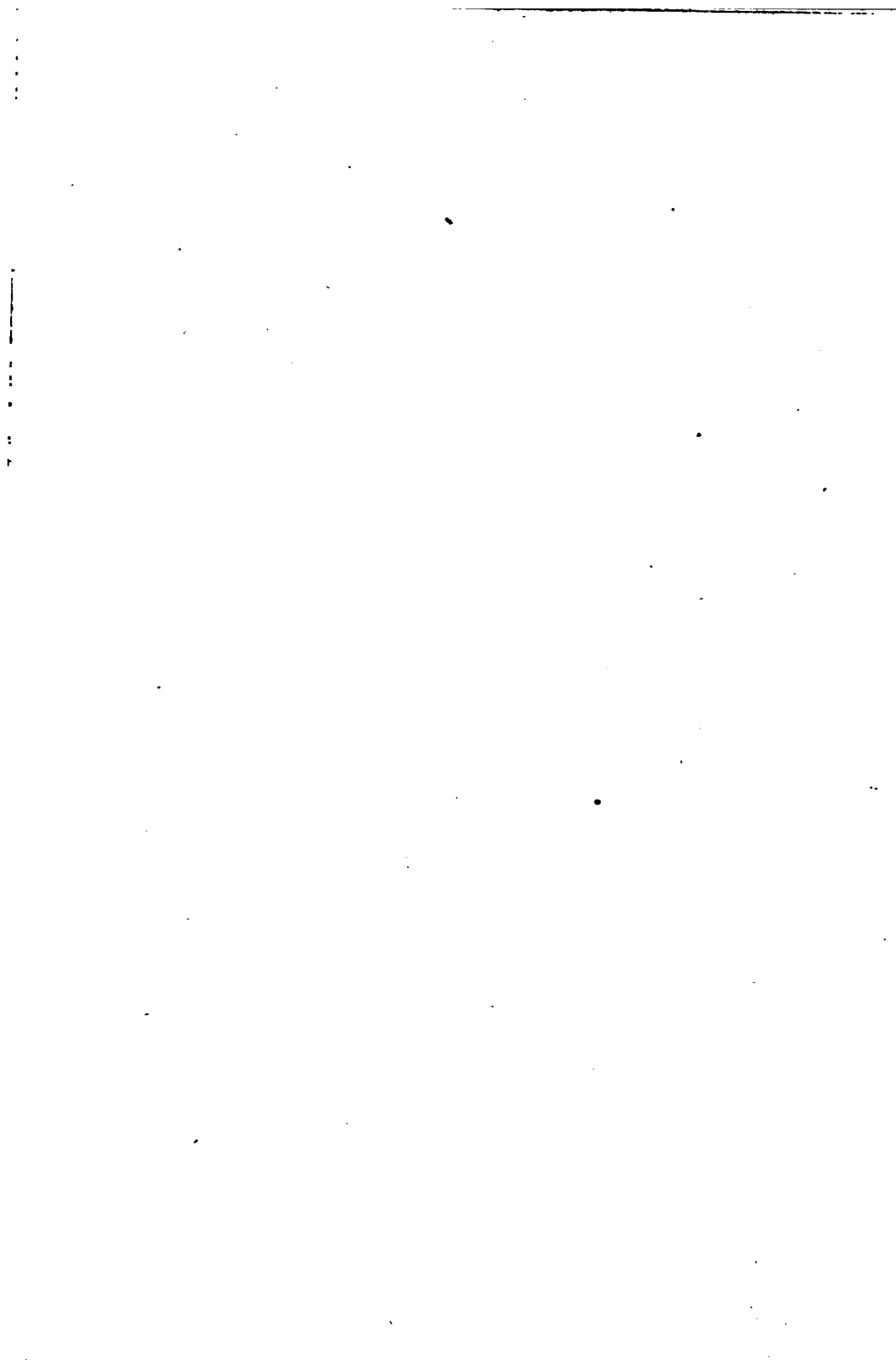
Smuts of cereals are fairly common, but all destructive smuts can be easily controlled by proper treatment of the seed.

EXPERIMENTS AT DALHART AND CHILLICOTHE, TEX.

Grain sorghums such as milo, dwarf milo, and Blackhull kafir have given profitable yields at Dalhart, though not so high as at Amarillo.

The small grains, both winter and spring varieties, have been so damaged by winter killing, spring blowing, drought, and hail, as to show no profitable yields during the period covered by the experiments.

Experiments with small grains have been conducted cooperatively with the Office of Forage-Crop Investigations at Chillicothe, which is situated in Hardeman County, somewhat east of the true Panhandle, at an elevation of only 1,500 feet and with an average annual rainfall of 23 inches. The results are similar to those obtained at Amarillo, the hard winter wheats giving the best yields and proving the most profitable small-grain crop. The grain sorghums are important and completely adapted crops, milo, dwarf milo, and Blackhull kafir being largely and profitably grown.



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Issued October 16, 1913.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 284.

WILLIAM A. TAYLOR, *Chief of Bureau.*

THE WATER REQUIREMENT OF PLANTS.

I.—INVESTIGATIONS IN THE GREAT PLAINS IN 1910 AND 1911.

BY

LYMAN J. BRIGGS,

Biophysicist in Charge of Biophysical Investigations,

AND

H. L. SHANTZ,

*Plant Physiologist, Alkali and Drought Resistant
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BUREAU OF PLANT INDUSTRY.

Chief of Bureau, WILLIAM A. TAYLOR.
Assistant Chief of Bureau, L. C. CORBETT.
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., June 16, 1913.

SIR: I have the honor to transmit herewith a paper entitled "The Water Requirement of Plants. I.—Investigations in the Great Plains in 1910 and 1911," by Dr. Lyman J. Briggs, Biophysicist in Charge of Biophysical Investigations, and Dr. H. L. Shantz, Plant Physiologist, Alkali and Drought Resistant Plant Investigations. This paper deals with the amount of water required by different crops for the production of a pound of dry matter or of grain and includes comparative tests of several varieties of the same crop in a number of instances. The work has for the most part been conducted at the dry-land experiment station at Akron, in northeastern Colorado. The results of the investigation have a direct bearing upon the selection of crops for use in semiarid regions, since, other things being equal, it is evident that those varieties which have the lowest water requirement are best suited to regions of limited rainfall.

The writers desire to express their obligation to Mr. E. C. Chilcott, Agriculturist in Charge of the Office of Dry-Land Agriculture, and to Mr. O. J. Grace, superintendent of the Akron Experiment Farm, for courtesies extended in connection with this investigation; to Mr. E. F. Chilcott, now superintendent of the Garden City Experiment Substation, Kansas, for conducting the tests at Amarillo, Tex., in 1910; to Mr. F. L. Kennard, now a member of the Idaho Agricultural Experiment Station staff, and to Mr. W. D. Griggs, of the Office of Dry-Land Agriculture, for conducting the experiments in 1911 at Dalhart, Tex.; to Prof. A. F. Kidder, of the Louisiana State University, and Mr. Homer Martin for efficient assistance in the field and pot experiments at Akron, Colo., in 1910; and to Messrs. Homer Martin, Alan Peter, and Auguste Boncquet for painstaking assistance in the Akron experiments in 1911.

I have the honor to recommend that this paper be published as Bulletin No. 284 of the Bureau series.

Respectfully,

WM. A. TAYLOR,
Chief of Bureau.

Hon. D. F. HOUSTON,
Secretary of Agriculture.

1. The first part of the document is a list of names and titles, including the names of the authors and the titles of the works.

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THE WATER REQUIREMENT OF PLANTS.¹

I.—INVESTIGATIONS IN THE GREAT PLAINS IN 1910 AND 1911.

INTRODUCTION.

The term "water requirement" is used in this paper to indicate the ratio of the weight of water absorbed by a plant during its growth to the weight of dry matter produced. The water requirement of a grain-producing field crop may be expressed either in terms of the total dry matter produced or on the basis of the grain alone and is found by dividing the total weight of the water absorbed during the whole period of growth by the total dry weight or by the weight of the grain, respectively. The results of earlier investigations have shown that some of the crop plants differ materially as regards their water requirement. The subject thus becomes one of considerable economic importance in connection with the agriculture of semiarid regions, since the crop or variety which is most economical in the use of water, other things being equal, is evidently the one best adapted to regions having a limited water supply.

The water requirement of a given crop, or the transpiration ratio, as it is sometimes called, has long been known not to be constant, but to be dependent upon and influenced by variations in many environmental factors, such as the temperature and humidity of the air, the velocity of the wind, the intensity of the solar radiation, and the fertility of the soil. The water requirement of small-grain crops grown in a cool, humid region is much lower than that of the same crops when grown in a dry region, such as the western part of the Great Plains, where they are subjected also to high winds and greater solar radiation.

It has consequently seemed desirable to determine at different points in the Great Plains the water requirement of the crop plants which have appeared best adapted to these regions. These experiments have included also the measurement of the water requirement of several different varieties of each of the more important crop plants under conditions designed to make the results as nearly comparable

¹ The investigations here described were carried on at every stage in cooperation between the Office of Biophysical Investigations and the Office of Alkali and Drought Resistant Plant Investigations. The names of the authors have been placed alphabetically on the title-page.

as possible, with a view to determining those varieties which are most efficient in the use of water.¹

The writers have also attempted the measurement of the water requirement of crops growing under field conditions. Such measurements are of practical value in determining the total amount of water used in the production of the crop. The uncertainty regarding the amount of run-off and of surface evaporation makes such determinations rather indefinite so far as the actual water requirement of the crop itself is concerned. It seemed very desirable, however, to obtain this field check upon the results of the pot experiments, and a gratifying agreement between the two series has been obtained.

DETERMINATION OF THE WATER REQUIREMENT OF CROPS IN POT CULTURES.

EXPERIMENTAL METHODS.

The determination of the amount of water used by a crop necessitates the measurement (1) of the amount of water added to the soil during the growth of the crop and (2) of the difference in the water content of the soil at the beginning and at the end of the experiment. The most accurate way of making the second determination is by weighing the whole system. Weighing also furnishes the best method of determining whether the soil contains at all times a suitable moisture supply for the crop. Weighing, however, necessitates the use of a pot or soil container of some kind, and this constitutes a departure from field conditions. However, in a comparative study of the water requirement of different crops, grown as nearly as possible under the same conditions, a rational pot culture may fairly be assumed to affect the different crops in a nearly uniform way and therefore to introduce no serious error in determining the relative water requirements of the several crops compared.

PREVENTION OF EVAPORATION.

Some uncertainty in determining the water requirement always results from the evaporation of water directly from the soil surface. A check pot without plants, in which the soil surface is freely exposed, can not safely be held to represent the loss by evaporation from the soil surface of a pot in which plants are growing. This is sufficiently demonstrated by considering the difference in the amount of evaporation from the check pots themselves. (Leather, 1910, p. 141.)² The growing plant, according to the character of its foliage and the

¹ A large amount of work by other investigators has already been done in connection with the determination of the water requirement of plants. The researches bearing on this subject, however, do not appear to have ever been brought together, and this has led the writers to present the results of different investigations in some detail in another publication (1912, B. P. I. Bul. 285).

² Bibliographic citations in parentheses in the text of this bulletin refer to the "Literature cited," p. 49.

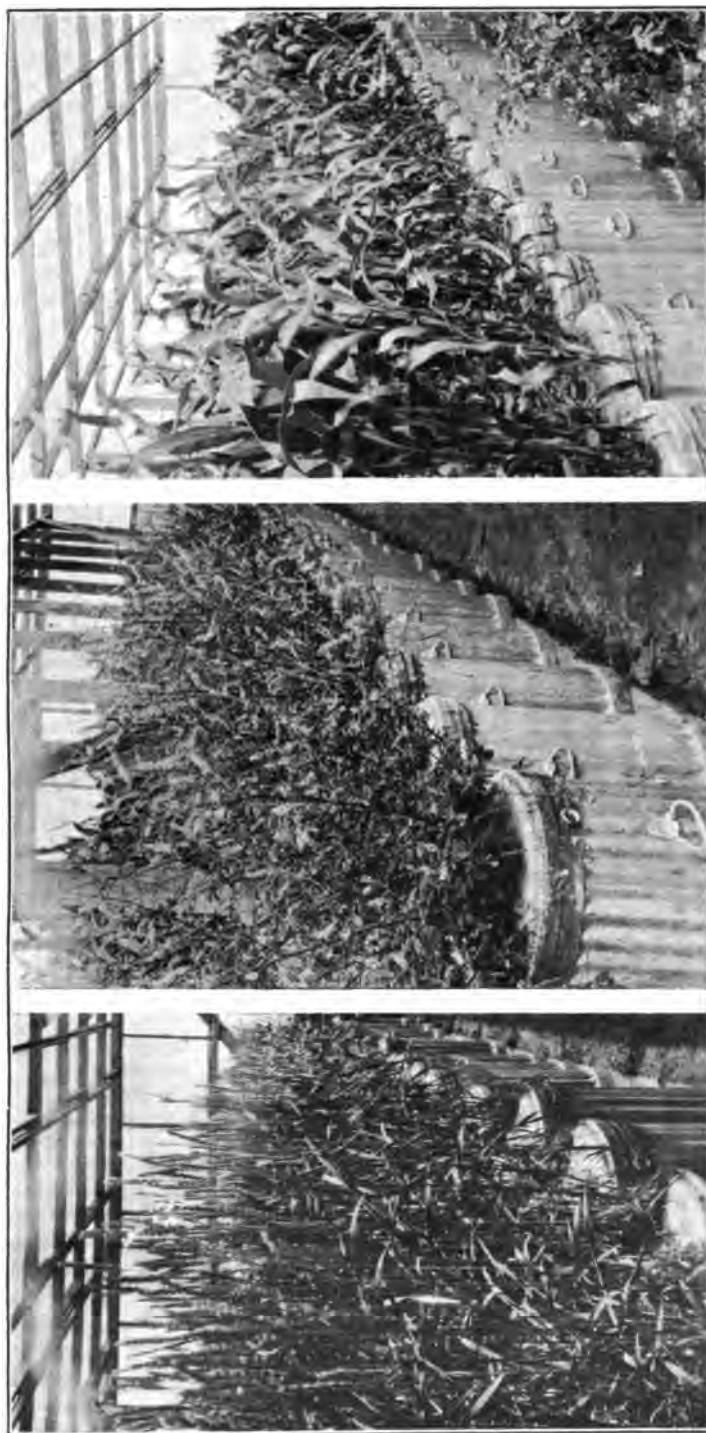


FIG. 1.—GALGALOS WHEAT.

FIG. 2.—SWEET CLOVER.

FIG. 3.—BLACKHULL KAFIR.

GENERAL VIEWS IN THE SHELTER AT AKRON, COLO., JULY 13, 1911.



FIG. 1.—GENERAL VIEW OF THE SHELTER USED IN THE EXPERIMENTS DURING 1911.



FIG. 2.—METHOD OF TRANSPORTING CANS.



FIG. 3.—METHOD OF WEIGHING CANS.

distribution of its root system, will also materially modify the surface evaporation from the soil. Kiesselbach and Montgomery (1911) have found that the loss of water from the soil surface can be minimized by the use of a 3-inch layer of gravel combined with a loosely fitting metal cover without interfering with the normal development of the corn plant. Lawes (1850) in his pioneer experiments closed the top of his pots with a tight-fitting cover, save for a small opening around the plants. The objection to closing the pots completely has, of course, been based upon the fear that the aeration would thereby be reduced to such an extent as to interfere with the normal development of the plants. It is evident, however, that the reduction of evaporation by the layer of gravel or by the closely fitting cover employed by Lawes must reduce the aeration to a corresponding degree, since the exit of water and the entrance of air under such conditions are both diffusion processes. The writers accordingly determined to try the expedient of eliminating the loss of water due to evaporation by using pots with tight-fitting covers provided with openings for the plants and sealing the openings around the stems of the plants as perfectly as possible with wax. It was believed that sufficient aeration would be secured (1) from the air which is drawn into the soil to replace the water transpired and subsequently expelled in part when more water is added; (2) from the air actually dissolved in the water added to the pots; and (3) from the air drawn into the pots by the contraction of the air in the interstitial spaces of the soil mass due to the daily fluctuations in temperature.

The results of the experiments have shown that this conclusion was justified. The growth was luxuriant and healthy (Pl. I), and the roots were found at the conclusion of the experiments to have penetrated into every portion of the soil mass. There was no tendency on the part of the root system to become massed either about the center of the pot, where the moisture was added, or at the walls, and there was no odor other than that of well-aerated soil.

DESCRIPTION OF THE POTS.

Substantial cans of heavily galvanized corrugated iron have been used in our experiments as soil containers for growing the experimental plants. (Pl. II, figs. 2 and 3.) Cans of one size have been used throughout, namely, 16 inches (40 cm.) in diameter and 26 inches (66 cm.) high, having a capacity of about 250 pounds (115 kilos) of soil. (Fig. 1.) Cans of this size provide a soil mass fully adequate for the normal development of the plants and are capable of being readily transported. (Pl. II, fig. 3.) The advantages of a large container have been noted by Leather (1910, p. 167). Each can is fitted with a heavy galvanized-iron cover through which holes are punched, suitable in size and number to accommodate the crop which

it is desired to grow. For the small-grain crops, 20 holes one-half inch in diameter have been used; for sorghum and alfalfa, 8 holes 1 inch in diameter; and for corn and sugar beets, 6 holes $1\frac{1}{2}$ inches in diameter. In the center of each cover is a hole $1\frac{1}{2}$ inches in diameter which is used for watering and which is normally kept closed with a stopper. These holes are punched so as to turn the edge upward and outward. The joint between the can and cover is sealed with a strip of surgeon's adhesive plaster 2 inches wide. Each can is provided with two heavy bale ears for suspending the can while weighing; also two folding handles.

FILLING THE POTS.

The soil, containing a sufficient amount of moisture to work well, is tamped into the cans. Especial care is taken to have the soil at the top of the pots built up above the can and well compacted, so as to be in firm contact with the cover. Otherwise a settling of the soil will subsequently occur and break the wax seals around the stems of the plants.



FIG. 1.—Pot used in measuring the water requirement of plants.

Before applying the cover, an excavation is made in the center of the soil in the can, into which a 5-inch unglazed flowerpot is inserted at such a height that the top of the pot will be in contact with the cover when the latter is in place. (Fig. 1.) The soil immediately around the lower part of the flowerpot is replaced by fine gravel. This arrangement provides additional surface for the absorption of water, so that the cans usually take water readily, thus greatly facilitating the process of watering. A vertical

section of the can showing the unglazed pot in position surrounded by gravel is shown in figure 1.

PLANTING AND SEALING.

The seeds, after having been kept between moist blotters until germination has started, are planted through the openings in the cover of the pot, moist soil being packed lightly over the seed to the level of the cover. The exposed soil surface is then protected from evaporation by a thin layer of wax, which can be quickly applied in a melted condition with a brush. The wax which we have found most satisfactory for this work consists of a mixture of 8 parts of pure beeswax and 2 parts of tallow. Most plants will readily push through this wax. After the plants have become established, the wax seal

can be thickened. This method of preventing evaporation and excluding rain has proved satisfactory and is especially useful in the case of the small grains. (Briggs and Shantz, 1912.)

Surgeon's adhesive plaster has also been used for closing the opening around the stem of the plant. After the seeds are planted, the top of the pot is covered with soil until the plants have appeared through the openings. The loose soil is then removed and a small square of adhesive plaster, cut through to the center from one side, is slipped around the seedling, and pressed into firm contact with the cover. The adhesive tape does not accommodate itself to the growth of the plants as well as the wax and is not as satisfactory in preventing the entrance of rain water. The seals of either material need occasional attention to keep them in good condition.

METHOD OF WATERING.

Water was added by means of 2-liter flasks, the necks of which were cut so as to deliver 2 liters when brimful. This form of flask could be filled quickly and accurately by immersion without further adjustment. The filled flask was inverted in a funnel placed in the opening in the center of the cover. This arrangement acted virtually as a Mariotte system, keeping the water at constant level in the receiving flowerpot until the flask was emptied. (See fig. 2.) When not watering, the hole in the lid was closed with a long cork stopper. The quantity of water added at one time was always 2 liters or a multiple thereof. This method of procedure, combined with the weighings made every second day, formed a valuable check upon the amount of water added, since it was always possible to determine from the weighings of a series of pots whether water had been added to any particular pot and the approximate quantity. Otherwise some uncertainty will occasionally arise regarding the amount of water added to a particular pot when 600 liters or more are being added to the whole series daily.

The water used was pumped from a deep well and carried some lime.

WEIGHING THE POTS.

The daily weighings were made upon a spring balance with a 12-inch dial having a capacity of 150 kilograms and readable to 0.1 kilogram. At Akron in 1911 this balance was checked frequently with a platform balance with agate beam bearings and having a sensibility of 5 grams, and in 1910 daily with a check pot which contained no plants and was

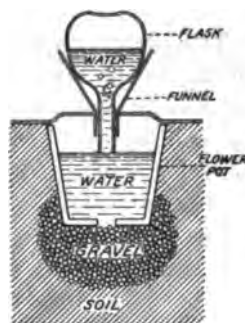


FIG. 2.—Sketch showing the device used in adding water to the pots.

completely sealed. Spring balances have a rather large temperature coefficient, which does not affect the results of this work, however, except in the initial and final weighings. Here the temperature correction, which may amount to several tenths of a kilogram with a load of 100 kilos, must be known or the balance must be checked frequently with a standard weight. The latter plan has been followed in our work.

For convenience in weighing, a steel track was installed in 1911 directly over each row, being fastened to the roof timbers of the inclosure. This track supported a small trolley, which in turn carried the lifting device and the balance. A small differential block was at first used to lift the pots. But the passage of the chain over the blocks caused the balance to vibrate badly while the pot was being lifted, so a double block and rope tackle was later substituted, one person holding the can suspended while a second recorded the weight. (Pl. II, fig. 2.) In this way the pots could be weighed at the rate of about one a minute.

CROPPING AND DRYING.

The plants growing in the pots were harvested at the stage when similar crops are harvested in the field. Grain crops were ripe and alfalfa and sweet clover were in flower. The plants were cut even with the soil surface, except that alfalfa and sweet-clover plants were cut in such a way as to leave the crown uninjured, and were placed in sacks of known weight. The green weight was taken and the cropping allowed to become air dry. It was then placed in a steam drying oven and maintained at a temperature of 110° C. until reduced to constant weight. The total dry weight, the weight of the sack, and the weight of grain were then determined.

THE SCREENED INCLOSURE.

To protect the plants from birds and possible hailstorms, it has been necessary to conduct the pot experiments in a screened inclosure. The inclosure at Akron in 1911 (Pl. II, fig. 1) was 36 by 40 feet and accommodated 200 pots, arranged in five double rows running east and west, with walks between. The framework was constructed of 2 by 4 inch studding, with a flat roof 10 feet above the ground. The roof timbers were spaced at intervals of 3 feet, to which the $\frac{1}{4}$ -inch galvanized network was tacked. The walls of the inclosure to a height of 3 feet consisted of tight boards. To break the force of the wind during storms, a strip of thin cheesecloth 3 feet wide was placed over the netting immediately above the board base. A strip of 2-inch mesh wire netting was placed over the cheesecloth, so that it was supported by netting on both sides. This thin cloth screen did not appear to interfere with the ventilation of the inclosure, the plants moving in the lightest breeze, but it served effectually to break the

force of high winds. This protection would not introduce any serious error in the determination of the water requirement, since an increase in the wind velocity above a moderate breeze has only a slight influence on the transpiration of a freely exposed plant. (Brown, 1910.)

EFFECT OF THE SHELTER ON THE WATER REQUIREMENT.

The plants grown in the inclosure were shaded to some extent by the network. This amounted to a reduction of about 26 per cent in the direct radiation from the sun at 10.30 a. m., based upon measurements with a silver disk pyrheliometer inside and outside the inclosure. Nearly half of the radiation thus cut off directly would, however, enter the inclosure indirectly by reflection and radiation from the screen, and the same would apply to the radiation from the sky. In addition to the effect of the screen, some shading resulted from the framework. An idea of this can be gained from Plate II, figure 2. The reduction in radiation, while so small as probably to have no effect on assimilation, would tend to reduce the water requirement of the plants in the inclosure compared with plants grown outside, since the inside plants were not required to dissipate so large an amount of solar radiation.

To test experimentally the effect of the inclosure, 12 standard pots of one of the tumbleweeds, *Amaranthus graecizans*, were grown from August 5 to September 15, 6 pots being placed inside the inclosure, while the others were left outside in a freely exposed position. The mean water requirement of each series (p. 33) was as follows:

Inside the inclosure.....	277±4
Outside the inclosure.....	275±7

These results would indicate that the effect of the slight shade and protection of the inclosure had no influence on the water requirement of this plant, the difference in the two series being less than the probable errors of observation. The difference in the radiation intensity inside and outside the inclosure can not, however, be regarded as without effect upon the transpiration of more succulent plants. Later experiments with wheat and alfalfa have shown that the use of a screen similar to that of the inclosure reduces the water requirement measurably. The absolute value of the water requirement obtained in the inclosure is, therefore, probably somewhat below that of an isolated plant growing in a freely exposed position. Under field conditions, however, the plants grow in close proximity and shade one another to some extent. The conditions in the inclosure therefore appear to approximate field conditions more closely than if the plants were grown in the open. The determination of the relative water requirement of the different crop plants is, however, the main problem from an economic standpoint. Aside

from a possible differential effect when widely separated genera are used, which is suggested by the results obtained with *Amaranthus graecizans*, it does not appear that the *relative* water requirement of the different plants would be measurably affected by the slight shading due to the inclosure.

COMPUTATION OF THE WATER REQUIREMENT.

Each pot is weighed (with an error of not more than 100 grams at most) soon after the seeds are planted and again immediately after the crop is harvested. The initial minus the final weighing when added algebraically to the water supplied, expressed in the same units, gives the total weight of water absorbed by the plant. This method of calculation gives a water consumption that is too high by an amount equal to the dry weight of the tops and too low by an amount equal to the green weight of the roots—errors which offset each other in part.

Each water-requirement determination in our experiments is based upon measurements carried on simultaneously in six pots. The water requirement of the plants in each pot is determined separately and the mean of the six determinations taken to represent the water requirement of the plant under investigation. This procedure also affords a basis for computing the probable error of the mean water requirement.¹

WATER REQUIREMENT OF WHEAT AND SORGHUM IN COLORADO AND TEXAS, 1910.²

The results of the water-requirement measurements of wheat and sorghum in 1910 at Akron, in northeastern Colorado, and at Amarillo, near the center of the Panhandle of Texas, including data for the individual pots, are given in Table I. In this series of experiments the water was not applied at the top of the pot, as already described, but was led through a small pipe to a gravel layer in the bottom of the pot. This method was not found satisfactory. The

¹ To those unaccustomed to thinking in terms of "probable error" it may be said that the probable error serves as a measure of the extent of the agreement among the individual observations. The more nearly the individual observations agree, the smaller is the probable error. If the experiments had been conducted with 12 cans instead of 6, and if both sets were representative, the chances are even that the mean of the second lot (m_2) would have agreed with the mean of the first lot (m_1) within the limits of the probable error ($\pm a$) of the latter; or, algebraically, that $m_1 + a > m_2 > m_1 - a$. The chances are 4.5 to 1 that the mean of the second set will agree with the first within limits equal to twice the probable error, i. e., 4.5 to 1 that $m_1 + 2a > m_2 > m_1 - 2a$, and similarly, 21 to 1 that $m_1 + 3a > m_2 > m_1 - 3a$.

The probable error of the difference of two means, each affected with a probable error, is equal to the square root of the sum of the squares of the two probable errors. If the difference of the two means is no greater than its probable error, the chances are even that the difference is fictitious. If the difference of the means is twice its probable error, the chances are 4.5 to 1 that a measurable difference exists between the two series; and, similarly, if the difference is equal to three times its probable error the chances are 21 to 1 that the series are measurably different. This last is often taken as the criterion of an actual difference in two series.

² The writers are indebted to Mr. E. F. Chilcott for conducting the tests at Amarillo, Tex., in 1910, and to Prof. A. F. Kidder and Mr. Homer Martin for assistance at Akron, Colo., during the same year.

upward capillary movement, particularly in the case of the Akron soil, was so slow that it was impossible to maintain the upper part of the soil mass at a suitable moisture content without getting the lower part too wet. This virtually decreased the soil mass and may be responsible in part for the higher water requirement obtained in 1910 as compared with 1911. The soil used at Akron in 1910 was not as productive as that used in the 1911 experiments, and this may also have increased the water requirement.

TABLE I.—*Water requirement of wheat and sorghum.*

AKRON, COLO., 1910.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Kubanka wheat, G. I. 1440 (<i>Triticum durum</i>), Apr. 18 to Aug. 2.	1	29.2	.....	21.38	.....	.....	732
	2	53.5	.....	36.65	.....	.....	685
	3	45.1	.....	22.90	.....	.....	508
	4	26.85	.....	20.68	.....	.....	770
	5	22.4	.....	13.14	.....	.....	586
	6	25.5	.....	17.97	.....	.....	705
Mean.....							664±30
Red Amber sorghum, S. P. I. 17548 (<i>Andropogon sorghum</i>), May 25 to Sept. 28.	25	112.9	.....	42.1	.....	.....	373
	26	126.0	.....	46.3	.....	.....	367
	27	153.7	.....	62.0	.....	.....	403
	28	180.5	.....	57.4	.....	.....	318
	29	164.8	.....	58.5	.....	.....	356
	30	234.6	.....	75.0	.....	.....	320
Mean.....							356±9

AMARILLO, TEX., 1910.

Kubanka wheat, G. I. 1440 (<i>Triticum durum</i>), Apr. 5 to July 19.	1	93.6	21.1	83.3	23	3,940	890
	2	73.3	15.4	68.2	21	4,430	930
	3	102.7	23.2	87.1	23	3,750	848
	4	81.9	18.8	64.8	23	3,440	791
	5	92.4	21.4	80.1	23	3,740	868
	6	114.3	31.5	90.4	28	2,870	790
Mean.....						3,695±140	853±16
Red Amber sorghum, S. P. I. 17548 (<i>Andropogon sorghum</i>), May 10 to Aug. 28.	7	334.9	81.0	114.1	24	1,419	341
	8	302.0	57.1	108.1	19	1,894	358
	9	326.2	72.8	120.3	22	1,653	369
	10	359.4	43.1	126.6	12	2,938	352
	11	336.6	78.2	121.9	28	1,558	363
	12	340.3	67.6	126.3	20	1,879	371
Mean.....						1,890±130	350±3

SUMMARY OF RESULTS IN 1910.

Crop.	Location.	Mean water requirement based on—	
		Grain.	Dry matter.
Wheat.....	Amarillo, Tex.....	3,695±140	853±16
	Akron, Colo.....		664±30
Sorghum.....	Amarillo, Tex.....	1,890±130	350±3
	Akron, Colo.....		356±9

It will be noted that the water requirement of wheat based on the dry matter produced was about 28 per cent higher at Amarillo than at Akron, while that of the sorghum was the same in both cases. The yield of grain was poor in each case, and no weight is to be attached to the water requirement of the grain. The variety of sorghum used is grown for forage only.

WATER REQUIREMENT OF WHEAT AND SORGHUM IN TEXAS, 1911.¹

The water-requirement measurements at Dalhart, Tex., in 1911 were confined to two crops, wheat and sorghum. This station is located in the extreme northwestern part of the Panhandle of Texas, and has an elevation of about 4,000 feet and an annual rainfall of about 16 inches. Sorghum is one of the best crops of this region, while wheat is uncertain. Six standard pots of each crop were grown in a screened inclosure of the same type as that used at Akron in 1911, but smaller. This was placed in a freely exposed position, so that the crops were subjected to the strong winds of that region. The pots were placed in two rows running east and west, the sorghum being placed on the north side to avoid shading the wheat. The period of growth was chosen to conform as nearly as possible to that of the same crops in the field. A summary of the results is given in Table II. The water requirement of the wheat based on dry matter was 673 ± 17 . The water requirement based on grain was 3,830. Comparing these results with similar measurements made at Akron, Colo., the same year (p. 17), it will be seen that the wheat grown at Dalhart required 43 per cent more water than at Akron for the production of the same amount of dry matter and 230 per cent more water for the production of the same amount of grain. This discrepancy in the ratios, combined with the low grain yield in the pots at Dalhart, leads the writers to question the water-requirement ratio obtained for grain at this station.

The water requirement for Red Amber sorghum at Dalhart in 1911 was 313 ± 10 when based on dry matter and $1,092 \pm 47$ when based on grain. This is only 5 per cent higher than the water requirement for this variety at Akron during the same year (p. 27), while the water requirement based on grain is 27 per cent less than at Akron. It should be stated in this connection that Red Amber sorghum is a variety grown for forage rather than for seed.

¹ The writers are indebted to Mr. F. L. Kennard and Mr. W. D. Griggs for conducting the tests at Dalhart, Tex., in 1911.

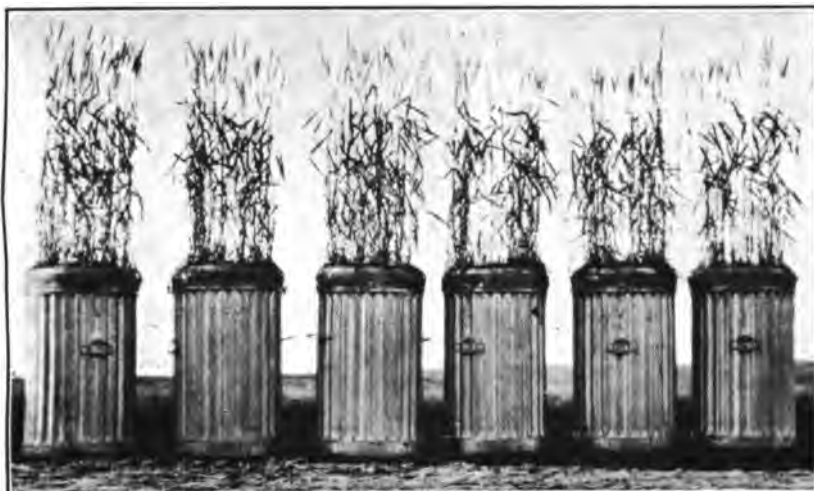


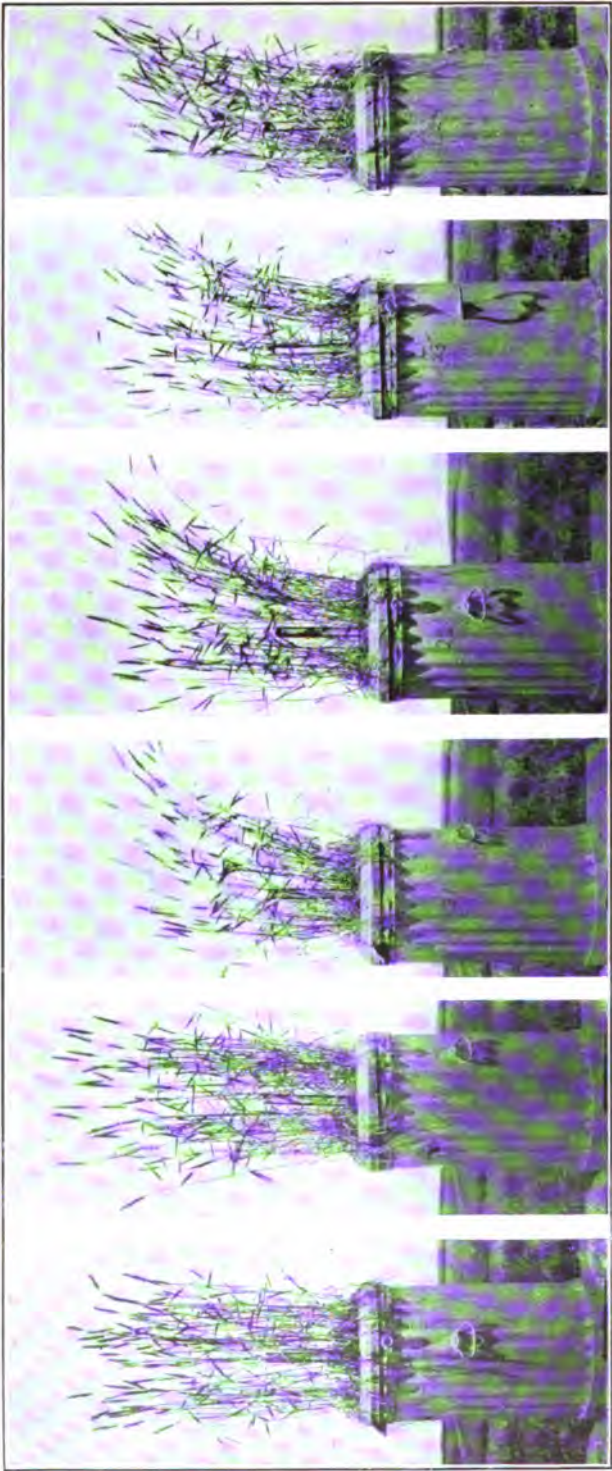
FIG. 1.—MARVEL BLUESTEM WHEAT, GROWN MAY 13 TO AUGUST 7, 1911 (POTS 13 TO 18).
Water requirement, 581 ± 5 .



FIG. 2.—SWEDISH SELECT OATS, GROWN MAY 13 TO AUGUST 7, 1911 (POTS 49 TO 54).
Water requirement, 615 ± 7 .



FIG. 3.—BELDI BARLEY, GROWN MAY 13 TO AUGUST 1, 1911 (POTS 61 TO 66).
Water requirement, 543 ± 2 .



GALGALOS WHEAT, GROWN MAY 13 TO AUGUST 1, 1911 (POTS 19 TO 24).
Water requirement, 496 ± 4.

TABLE II.—Water requirement of wheat and sorghum at Dalhart, Tex., in 1911.

Crop.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		Grams.	Grams.	Kilos.	Per cent.		
Kubanka wheat, G. I. 1440 (<i>Triticum durum</i>), Apr. 25 to July 18.....	1	48.4	8.4	29.9	17	3,560	618
	2	49.4	11.1	31.0	22	2,790	628
	3	48.7	8.5	31.4	19	3,600	719
	4	43.9	8.2	29.6	19	3,610	674
	5	41.8	6.3	31.8	15	5,020	761
	6	42.5	6.3	27.2	15	4,320	640
Mean.....						3,830±200	673±17
Red Amber sorghum (<i>Andropogon sorghum</i>), May 14 to Sept. 12.....	7	285.8	88.7	81.0	31	913	283
	8	274.2	72.7	81.4	27	1,119	297
	9	289.9	80.5	94.2	28	1,045	291
	10	243.9	67.2	88.1	28	1,310	361
	11	286.9	90.9	85.6	32	942	298
	12	241.3	68.1	83.3	28	1,223	346
Mean.....						1,092±47	313±10

WATER-REQUIREMENT MEASUREMENTS IN COLORADO, 1911.¹

Akron, Colo., where most of the water-requirement measurements described in this bulletin have been made, is a point in north-eastern Colorado about 100 miles east of Denver. It is an open, treeless, rolling plains country. Dry farming has received considerable attention, but most of the land is still covered with the native short grass. (Shantz, 1911.) The annual rainfall is about 18 inches, three-fourths of which falls during six months, April to September. The humidity is normally low, and the hot summer days are followed by cool nights. The sky is seldom perfectly clear and sunshine is frequently followed quickly by cloud. The storms are often extremely local in character and many times are attended with high winds and occasionally with hail. As Akron is located in the center of the Great Plains, from east to west as well as from north to south, the measurements serve also to represent roughly the water requirement of crops for the Great Plains as a whole.

WATER REQUIREMENT OF DIFFERENT VARIETIES OF WHEAT.

Five varieties of wheat, including one of emmer, were tested as regards their water requirements at Akron, Colo., in 1911. The series included one variety of *Triticum durum*, the Kubanka; three varieties of *Triticum aestivum*, Marvel Bluestem (Pl. III, fig. 1), Galgalos (Pl. IV), and Spring Ghirka; and one variety of *Triticum dicoccum*, or emmer. The Kubanka series consisted of 17 pots, 6 of which were fertilized. The unfertilized pots were distributed at the two ends of the inclosure, Nos. 1 to 6, inclusive, being at

¹ The writers are indebted to Messrs. Auguste Bonquet, Alan Peter, and Homer Martin for assistance in the Akron, Colo., experiments in 1911.

the 'south end and the remainder at the north end. Referring to Table III it will be seen that the mean water requirement of the unfertilized Kubanka wheat for the 11 pots was 468 ± 8 , while the water requirement of the grain alone was $1,196 \pm 15$. The pots of Kubanka wheat located at the north end of the inclosure appear to have a slightly higher water requirement. This part of the inclosure was occupied by the corn and sorghums, and since these latter plants did not reach any considerable development until the wheat was practically ripe the wheat plants in the north end of the inclosure were severely exposed to the winds during practically the whole period of growth. While the wind moved freely through the shelter at all times, the other plants were not whipped as were these isolated plants.

Six pots of Kubanka wheat, Nos. 7 to 12, inclusive, were fertilized, 20 grams of potassium nitrate and 20 grams of sodium acid phosphate being added to each pot. This amount of fertilizer was divided into five parts and each part was dissolved in a liter of water and added to the pots at intervals, additional water being added after the fertilizer. The water requirement of the fertilized Kubanka wheat was 422 ± 6 , while that of the grain alone was $1,184 \pm 36$. It thus appears that the use of fertilizer reduced the water requirement only slightly, so far as the total dry matter is concerned, the difference between the fertilized and unfertilized pots being about three times the probable error. In the case of the grain, the addition of fertilizer appeared to have no effect upon the water requirement. As we have already stated, the soil used in the experiments of 1911 was a rich, dark loam selected with the belief that no additional fertilizer would be required to give a minimum water requirement and the results indicate that sufficient plant food was available.

The other wheat varieties tested all gave a higher water requirement than Kubanka, the values obtained based upon the total dry matter being as follows:

Kubanka.....	468 ± 8
Galgalos.....	496 ± 4
Spring Ghirka.....	506 ± 3
Marvel Bluestem.....	531 ± 5
Emmer.....	534 ± 14

The grain requirement is in the same order as the dry-matter requirement except in the case of emmer, which gave a grain requirement practically identical with Kubanka wheat. In this connection it should be remembered that the "grain" of emmer includes the entire spikelet. The glumes or chaff constitute about 21 per cent of the weight of the harvested grain. Consequently the water requirement for the production of the true grain is 1,490. This value is now

comparable with the grain yields of the wheat varieties. The water requirement of the different varieties is then as follows:

Emmer (including glumes).....	1, 180±42
Kubanka.....	1, 191±14
Galgalos.....	1, 245±13
Spring Ghirka.....	1, 382±43
Emmer (without glumes).....	1, 490±53
Marvel Bluestem.....	1, 786±60

The above summary shows emmer to have a water requirement for grain production higher than any other wheat with the exception of the Marvel Bluestem.

It is of special interest to note that Marvel Bluestem, a variety grown extensively in humid regions, gave a higher water requirement, both for dry matter and for grain, than any of the other varieties of wheat tested, requiring 13 per cent more water than Kubanka wheat to produce an equal amount of dry matter, and nearly 50 per cent more to produce an equal amount of grain.

TABLE III.—Water requirement of different varieties of wheat at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Kubanka, G. I. 1440 (<i>Triticum durum</i>), May 13 to Aug. 2.....	1	110.6	43.9	49.5	40	1,128	448
	2	120.1	48.4	61.6	40	1,272	513
	3	87.4	33.1	39.9	38	1,205	456
	4	104.1	40.0	44.75	38	1,119	430
	5	113.4	45.6	50.9	40	1,116	449
	6	73.9	25.8	29.4	35	1,139	398
	199	84.8	35.6	40.5	42	1,138	477
	200	75.0	30.5	37.2	41	1,219	496
	202	90.5	36.1	47.3	40	1,310	523
	203	65.2	25.1	30.55	39	1,217	469
	204	110.6	43.8	54.45	40	1,243	492
Mean.....						1,191±14	468±8
Kubanka, G. I. 1440 (<i>Triticum durum</i>), May 13 to Aug. 2 (fertilized).....	7	92.6	32.7	36.45	36	1,114	394
	8	128.9	48.2	57.2	35	1,265	444
	9	79.7	24.7	34.4	31	1,392	432
	10	110.0	41.8	44.1	38	1,055	401
	11	114.8	44.0	50.15	38	1,139	437
	12	89.3	33.1	37.8	37	1,142	423
Mean.....						1,184±36	422±6
Marvel Bluestem, G. I. 3062 (<i>Triticum aestivum</i>), May 13 to Aug. 7.....	13	121.3	30.7	68.6	25	2,233	565
	14	120.4	38.0	61.95	32	1,630	514
	15	132.6	39.4	71.4	30	1,811	538
	16	127.0	38.7	67.1	31	1,734	528
	17	121.4	37.6	64.1	31	1,704	528
	18	140.2	44.7	71.6	32	1,602	510
Mean.....						1,786±60	531±5
Galgalos, G. I. 2396 (<i>Triticum aestivum</i>), May 13 to Aug. 1.....	19	108.5	43.9	54.65	40	1,244	490
	20	119.6	45.1	60.7	38	1,345	507
	21	104.5	42.2	52.65	40	1,247	504
	22	121.2	49.3	58.7	41	1,190	484
	23	106.2	43.3	52.0	40	1,200	490
	24	116.4	47.0	58.5	40	1,244	502
Mean.....						1,245±13	496±4

TABLE III.—Water requirement of different varieties of wheat at Akron, Colo., in 1911—Continued.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		Grams.	Grams.	Kilos.	Per cent.		
Spring Ghirka, G. I. 1517 (<i>Triticum aestivum</i>), May 13 to Aug. 4.....	25	113.2	30.5	55.9	35	1,415	494
	26	125.5	44.8	63.1	36	1,406	388
	27	120.2	38.2	63.2	32	1,654	526
	28	120.7	44.5	61.2	37	1,375	507
	29	109.1	39.2	54.6	36	1,393	500
	30	110.5	53.2	55.7	48	1,047	504
Mean.....						1,382±43	506±3
Emmer, G. I. 2951 (<i>Triticum dicoccum</i>), May 13 to Aug. 4....	79	111.1	50.9	52.3	46	1,027	471
	80	120.4	57.9	59.8	48	1,032	497
	81	120.5	52.1	71.8	43	1,378	596
	82	87.4	39.5	45.4	45	1,149	519
	83	103.4	46.0	57.7	45	1,254	558
	84	121.2	54.9	68.2	45	1,242	598
Mean.....						1,180±42	534±14

WATER REQUIREMENT OF DIFFERENT VARIETIES OF OATS.

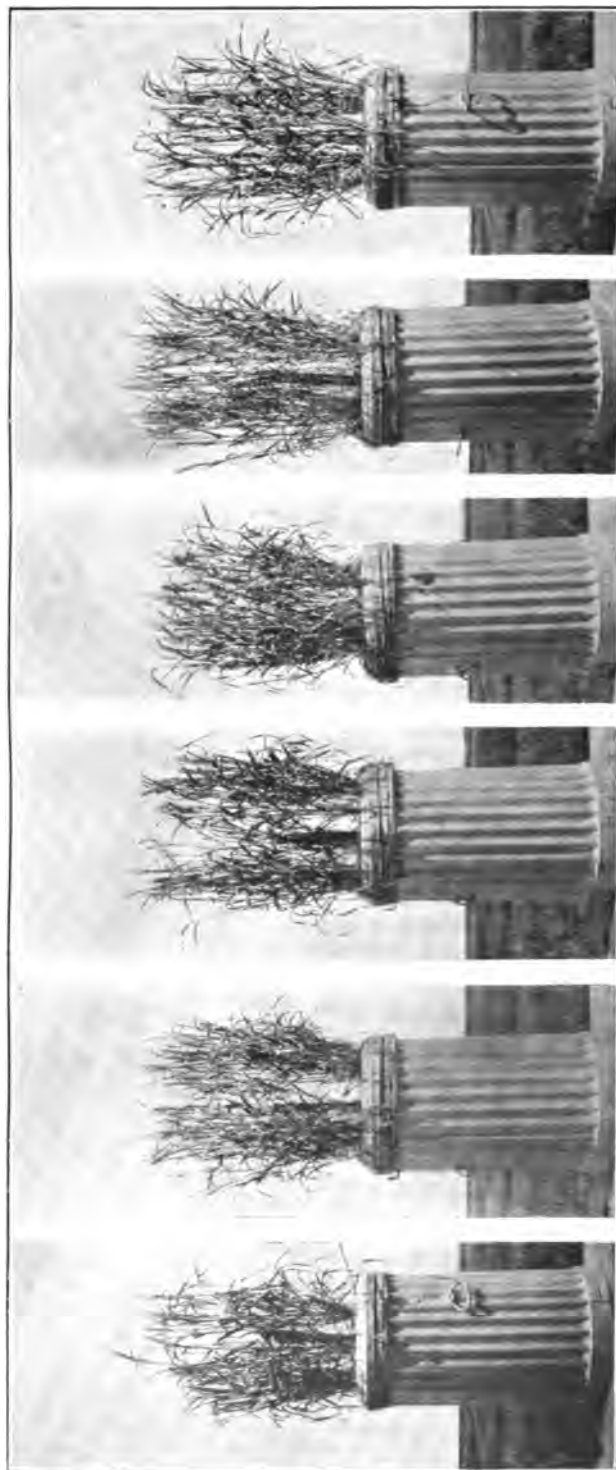
The experiments with oats at Akron, Colo., in 1911 included four varieties, namely, Sixty-Day, Canadian, Burt, and Swedish Select. (Table III and Pl. III, fig. 2.)

A summary of the water requirements of the different varieties of oats, based on dry matter, is here given:

Canadian.....	598±14
Sixty-Day.....	605±5
Swedish Select.....	615±7
Burt.....	639±7

Very little difference is shown by the different varieties in their water requirement when based on the production of dry matter; in fact, the difference between the Canadian and the Burt is less than three times the probable error. In the case of the Sixty-Day and the Burt the difference is four times the probable error, indicating a small but real difference in the water requirement of these varieties. This is of especial interest when we consider the growth habits of the different varieties. The luxuriant broad-leaved Canadian, a plant which seems ill adapted to a dry country, has apparently the lowest water requirement, while the least leafy plant, the Burt, has the highest. However, the small-growing Sixty-Day and Burt varieties are far more economical than the Canadian in the use of water when the grain yield is considered. This is shown in the following summary of the water requirement of the different varieties based on grain production:

Sixty-Day.....	1,383±30
Burt.....	1,500±57
Swedish Select.....	1,632±35
Canadian.....	2,204±140



HANNCHEN BARLEY, GROWN MAY 13 TO AUGUST 12, 1911 (POTS 55 TO 60).

Water requirement, 527 \pm 8.

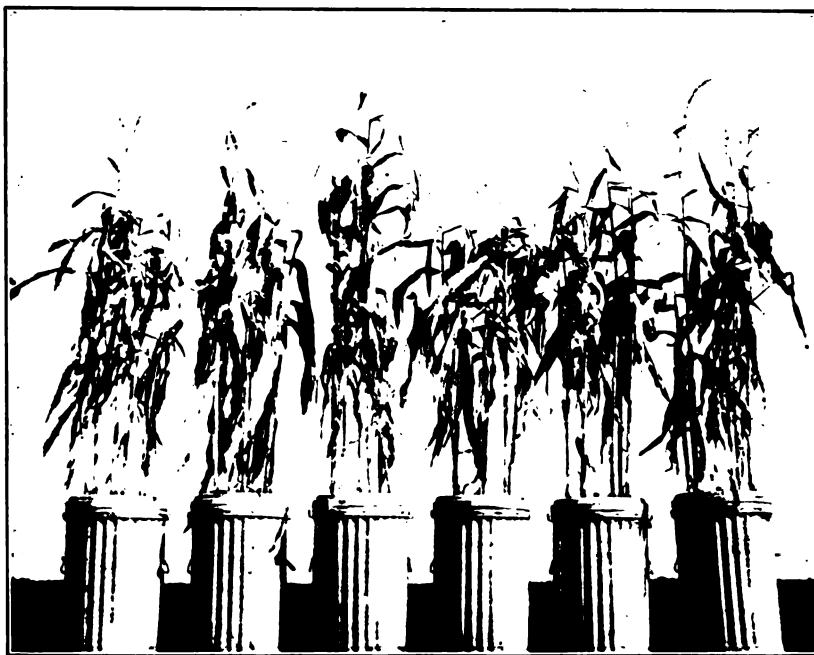


FIG. 1.—IOWA SILVERMINE CORN, GROWN MAY 24 TO SEPTEMBER 4, 1911
(POTS 115 TO 120).
Water requirement, 420 ± 8 .



FIG. 2.—WHITE DURRA, GROWN MAY 12 TO SEPTEMBER 5, 1911 (POTS 145 TO 150).
Water requirement, 321 ± 2 .

Swedish Select is intermediate both in habit of growth and in its water requirement based upon either dry matter or grain. As compared with Kubanka wheat, the oat plants appear to require about 30 per cent more water for the production of an equal amount of dry matter and even the best varieties of oats require 15 per cent more water than Kubanka wheat for an equal production of grain.

TABLE IV.—Water requirement of different varieties of oats at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Sixty-Day, G. I. 166 (<i>Avena sativa</i>), May 13 to Aug. 2.....	31	124.1	52.9	75.7	43	1,431	610
	32	117.1	53.7	71.0	46	1,321	606
	33	38.3	15.2	22.0	40	1,447	574
	34	119.3	53.6	71.4	45	1,332	598
	35	124.5	51.7	78.0	42	1,509	626
	36	138.0	67.0	84.55	49	1,262	613
Mean.....						1,383±30	605±5
Canadian, G. I. 444 (<i>Avena sativa</i>), May 13 to Aug. 12.....	37	46.5	8.2	25.7	18	3,134	553
	38	125.0	36.0	79.1	31	2,028	633
	39	135.2	46.2	81.3	34	1,759	601
	40	112.7	32.4	60.4	29	1,864	636
	41	125.8	41.6	84.8	33	2,038	674
	42	110.6	27.3	65.5	25	2,409	592
Mean.....						2,204±143	598±14
Burt, G. I. 293 (<i>Avena sativa</i>), May 13 to Aug. 12.....	43	137.6	53.5	90.9	39	1,698	660
	44	141.8	53.7	89.6	38	1,668	632
	45	180.8	75.2	106.9	47	1,422	665
	46	124.8	54.1	77.8	43	1,438	623
	47	143.6	73.3	87.0	51	1,187	606
	48	149.9	61.2	97.1	41	1,596	648
Mean.....						1,500±57	639±7
Swedish Select, G. I. 134 (<i>Avena sativa</i>), May 13 to Aug. 7.....	49	174.2	76.0	108.7	44	1,430	624
	50	181.2	67.7	109.3	37	1,615	603
	51	150.2	53.4	98.9	36	1,851	658
	52	172.0	62.4	103.3	36	1,660	601
	53	168.0	62.3	103.4	37	1,661	616
	54	196.7	73.3	115.4	37	1,575	587
Mean.....						1,632±35	615±7

WATER REQUIREMENT OF DIFFERENT VARIETIES OF BARLEY.

Four barleys, including three varieties of *Hordeum vulgare*, the Beldi (Pl. III, fig. 3), White Hull-less, and Beardless, and one variety of *Hordeum distichon*, the Hannchen (Pl. V), were included in the experiments at Akron, Colo., in 1911 (Table V). The results of the water requirement determinations with varieties of barley, based upon the dry matter produced, are as follows:

Hannchen.....	527±8
White Hull-less.....	542±3
Beldi.....	543±2
Beardless.....	544±9

Like the oats, the several varieties of barley tested showed practically no difference in the water requirement when based on dry matter, the agreement being even more striking. Thus, in the case of the three varieties of *Hordeum vulgare* the water requirement is 543 ± 2 , 542 ± 3 , and 544 ± 9 . The other species, *Hordeum distichon*, is slightly lower, namely, 527 ± 8 , but no weight can be attached to so slight a difference when the probable errors are considered.

When the water requirement is based upon the grain produced, three of the varieties are again in practical agreement. The White Hull-less is, however, a little higher than the others, and this hull-less character should be considered in comparing the water requirements. If the hulls are removed from the grain of the Beldi the water requirement is increased from 1,155 to 1,220, which is still much lower than the water requirement for the hull-less barley. The increase due to removing the hulls is even less in the case of Hannchen barley. It is evident, therefore, that the higher water requirement for grain production by hull-less barley is only partly due to the naked grain and that for the production of an equal amount of true grain the other varieties considered require somewhat less water. A summary of the water requirement of the different varieties of barley tested, when calculated upon the basis of grain produced, is given below:

Hannchen.....	1, 134 \pm 27
Beldi.....	1, 155 \pm 18
Beardless.....	1, 210 \pm 38
Beldi (hulled).....	1, 220 \pm 19
White Hull-less.....	1, 475 \pm 40

Here, again, a great difference exists in the habits of the plants, the Beldi being a dwarf variety with a stem so short as to make harvesting difficult, while the other varieties have a more luxuriant habit of growth, with numerous large well-developed leaves. From the results of these experiments barley appears to require about 15 per cent more water than Kubanka wheat for an equal amount of dry matter, being nearly midway between the oat plant and Kubanka wheat in its water requirement. In the production of grain the best varieties of barley require only about 5 per cent less water than does Kubanka wheat.

TABLE V.—Water requirement of different varieties of barley at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Hannchen, G. I. 531 (<i>Hordeum distichon</i>), May 13 to Aug. 12.	55	102.0	45.1	54.6	44	1,210	535
	56	149.8	66.2	71.3	44	1,077	476
	57	135.8	59.3	72.5	44	1,222	534
	58	146.0	64.1	75.7	44	1,181	518
	59	142.1	74.5	74.6	52	1,000	525
	60	142.3	73.6	82.0	52	1,114	576
Mean.....						1,134±27	527±8
Beldi, G. I. 190 (<i>Hordeum vulgare</i>), May 13 to Aug. 1.....	61	85.9	35.4	45.7	41	1,291	532
	62	92.3	45.9	50.4	50	1,098	546
	63	77.5	37.1	42.7	48	1,151	551
	64	97.6	45.7	52.8	47	1,155	541
	65	85.9	44.0	47.2	51	1,072	550
	66	100.4	46.4	54.0	46	1,164	538
Mean.....						1,155±18	543±2
White Hull-less, G. I. 595 (<i>Hordeum vulgare</i>), May 13 to July 31.....	67	107.0	43.2	60.7	40	1,405	567
	68	140.2	51.2	73.3	37	1,431	522
	69	114.2	48.2	61.1	42	1,268	535
	70	134.9	44.1	73.0	33	1,655	541
	71	104.6	38.0	56.8	36	1,494	543
	72	124.8	42.4	67.6	34	1,594	542
Mean.....						1,475±40	542±3
Beardless, G. I. 716 (<i>Hordeum vulgare</i>), May 13 to Aug. 1.....	74	119.5	57.6	64.7	48	1,123	542
	75	84.4	36.8	49.7	44	1,350	580
	76	106.2	48.6	58.9	46	1,211	554
	77	88.6	35.3	45.6	40	1,291	515
	78	70.0	33.9	36.4	48	1,073	520
Mean.....						1,210±38	544±9

WATER REQUIREMENT OF RYE AND BUCKWHEAT.

The determinations of the water requirements of rye and buckwheat (see Pl. X, fig. 3) at Akron, Colo., in 1911 were limited to one variety of each. The results are given in Table VI. From the table it appears that rye has a surprisingly high water requirement, the ratio of the water transpired to the dry matter produced being 724 ± 7 , or nearly 54 per cent more than for Kubanka wheat. The grain requirement is also exceptionally high, the plants requiring 2,200 pounds of water for the production of 1 pound of grain.

If these ratios are confirmed by subsequent tests, the use of rye as a soiling crop would appear to be a very doubtful expedient in regions of limited rainfall. Wheat, for example, would produce the same amount of dry matter with the expenditure of only two-thirds the amount of water required in the case of rye. Every 300 pounds of rye produced per acre means the removal of 1 inch of stored rainfall. The production of a moderate crop of 1,500 pounds of dry matter per acre means then the removal of 5 inches of stored water, unless the conditions are such that the necessary water for growth is supplied

through rains during the growing season. The removal of 5 inches of water would deplete the available stored moisture supply in the average semiarid cultivated soil of the Great Plains, even after summer fallowing for a season. It is doubtful, therefore, if rye should be used as a soiling crop on land that is to be planted to a money crop in regions of limited rainfall. Its use should at least be confined to the fall and early spring, when the water requirement, owing to the cooler weather, is considerably reduced. (See "Alfalfa," under "Water requirement of legumes," p. 29.)

In this connection it is interesting to consider the results obtained by Von Seelhorst for rye and wheat at Gottingen, Germany. (1906, 1908.) They are in practical agreement with our results, but Von Seelhorst is inclined to favor rye as a soiling crop, notwithstanding its higher water requirement, because its period of maximum consumption of water comes so much earlier in the season than does that of wheat. This allows the accumulation of water in the soil before the next crop is ready to use it. While this would be an important consideration in a region of ample and well-distributed rainfall, in a region such as the Great Plains the chief consideration is not *when* the water is removed but *how much* water is removed by the soiling crop.

Buckwheat gave a mean water requirement for the dry matter produced of 578 ± 13 , which is about 23 per cent higher than Kubanka wheat and intermediate between barley and oats. The water requirement of the grain in the case of buckwheat is, however, exceptionally low, being 13 per cent less than for Kubanka wheat and the lowest of all the small grains measured except millet.

TABLE VI.—Water requirement of rye and buckwheat at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Spring rye, G. I. 73 (<i>Secale cereale</i>), May 13 to Aug. 5.....	85	88.1	28.4	63.7	32	2,242	723
	86	89.0	28.5	69.5	32	2,439	781
	87	80.2	24.7	55.8	31	2,259	686
	88	78.4	25.4	55.9	32	2,200	713
	89	89.1	29.7	64.4	33	2,188	722
	90	88.6	31.7	62.8	36	1,981	709
Mean.....						2,215 \pm 37	724 \pm 7
Buckwheat (<i>Fagopyrum fagopyrum</i>), June 10 to Sept. 16....	193	109.9	62.5	57.7	57	923	525
	194	116.7	67.0	64.9	57	969	556
	195	67.1	35.1	39.9	52	1,137	594
	196	59.5	31.9	36.1	54	1,131	607
	173	93.3	55.3	56.8	59	1,027	609
Mean.....						1,037 \pm 33	578 \pm 13

WATER REQUIREMENT OF DIFFERENT VARIETIES OF CORN.

Three varieties of corn (*Zea mays*) were included in the water-requirement experiments at Akron, Colo., during the season of 1911. (Table VII.) Northwestern Dent is an early-maturing variety grown extensively in the northern part of the Great Plains, where the season is rather short for maize. Its water requirement was found to be 368 ± 10 . Iowa Silvermine (Pl. VI, fig. 1) is a variety which is very popular in corn-growing States and has a vigorous habit of growth, with well-developed leaves. Its water requirement was 420 ± 3 , which is considerably above that obtained for Northwestern Dent. Neither of these varieties gave so low a water requirement as did Esperanza, a drought-resistant Mexican variety introduced by Mr. G. N. Collins, of the Office of Crop Acclimatization and Adaptation Investigations. This variety gave a water requirement of 319 ± 5 , which is only about three-fourths of the water requirement of the Iowa Silvermine. Esperanza, however, produced no ears at Akron. Owing to our failure to secure a good pollination of the ears, no significance can be attached to the water requirement for the production of grain in the case of the different varieties of corn tested.

A comparison of the results obtained with corn and sorghum shows the surprising and important fact that Esperanza corn produced dry matter as economically as did Dwarf milo and white durra. Even the large, luxuriant Iowa Silvermine required only 26 per cent more water than the Dwarf milo, one of the most successful drought-resistant crops of the southern Great Plains. It would seem from these results that in corn we have a wonderfully efficient plant, and that varieties may be chosen which will compete successfully with plants of the sorghum group as regards economy in the use of water. Where corn is grown far apart and with only one plant in a hill, as is the practice in dry regions, and where the ground is kept free from weeds it is not surprising that the rotation of fall wheat after corn has in many places supplanted the rotation of fall wheat after summer tillage. While during extremely dry years grains give a greater money return when grown on summer-fallowed land, one year with another, the money return from the corn crop more than compensates for the lower grain yield during the exceptionally dry years.

TABLE VII.—*Water requirement of different varieties of corn at Akron, Colo., in 1911.*

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on —	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Northwestern Dent (<i>Zea mays</i>), May 24 to Aug. 23.....	109	179.0	72.8	55.2	41	758	308
	110	173.5	58.6	60.35	34	1,029	348
	111	154.1	28.2	58.75	18	2,083	381
	112	160.1	37.7	61.05	24	1,619	381
	113	151.8	25.3	61.45	17	2,429	405
	114	145.9	13.0	56.2	9	4,320	385
Mean.....						2,040 ± 342	368 ± 10
Iowa Silvermine (<i>Zea mays</i>), May 24 to Sept. 4.....	115	232.5		102.7			442
	116	260.5		104.55			401
	117	221.8		93.3			421
	118	224.2		93.85			415
	119	232.4		96.66			416
	120	237.7		100.0			421
Mean.....							420 ± 3
Esperanza, M. 66 (<i>Zea mays</i>), May 12 to Sept. 4.....	121	288.8		83.4			289
	122	262.6		84.7			323
	123	279.5		93.8			335
	124	317.9		103.1			324
	125	268.4		83.75			312
	126	287.0		95.85			334
Mean.....							319 ± 5

WATER REQUIREMENT OF DIFFERENT VARIETIES OF SORGHUM.

Five varieties of sorghum (*Andropogon sorghum*) (Pls. VI to VIII) were tested as regards their water requirements at Akron, Colo., in 1911. The data are given in detail in Table VIII. The water requirement of the five varieties, based on the dry matter, is as follows:

Blackhull kafir.....	278 ± 5
Red Amber sorghum.....	298 ± 4
Brown kaoliang.....	301 ± 3
White durra.....	321 ± 2
Dwarf milo.....	333 ± 3

The adaptation to dry-land conditions of this remarkable group of forage plants is well shown in their unusually low water requirement, which taken as a group is well below all the other plants tested, with the exception of Esperanza corn and millet. The excellent agreement of the individual pot experiments is shown by the small probable error and justifies considerable confidence in the results as indicating the relative water requirements of the different varieties tested. It would therefore appear that Dwarf milo requires about 20 per cent more water than Blackhull kafir for an equal amount of dry matter.

The other varieties are intermediate, Red Amber sorghum requiring about 7 per cent, Brown kaoliang 8 per cent, and White durra 15 per cent more water than the kafir.

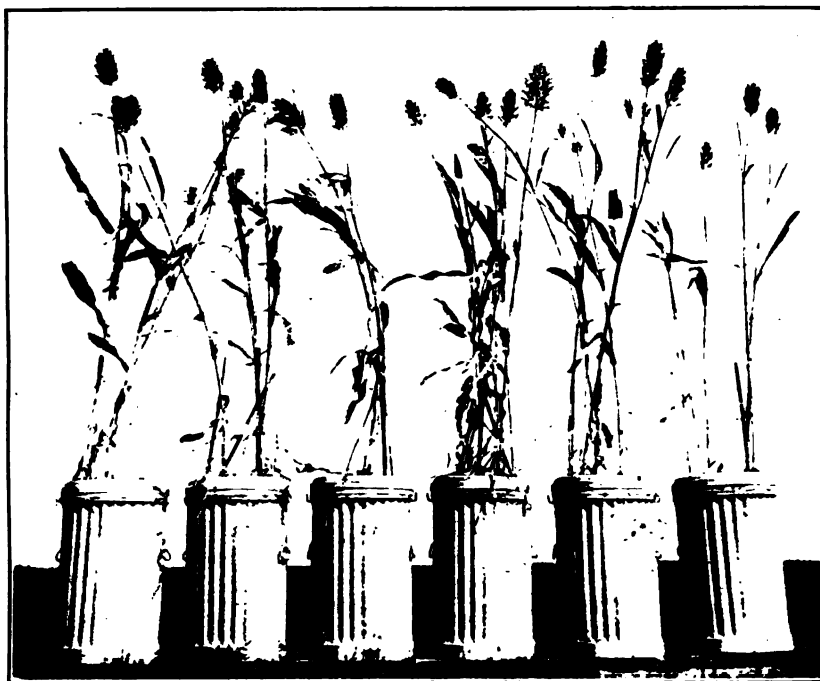


FIG. 1.—BROWN KAOLIANG, GROWN MAY 12 TO SEPTEMBER 6, 1911 (POTS 151 TO 156).
Water requirement, 301 ± 3 .



FIG. 2.—RED AMBER SORGHUM, GROWN MAY 12 TO SEPTEMBER 4, 1911
(POTS 127 TO 132).
Water requirement, 298 ± 4 .

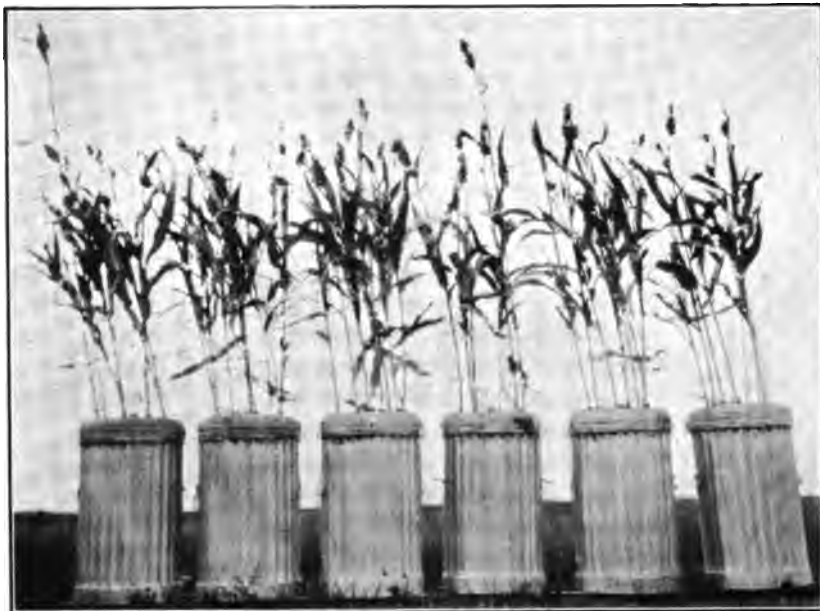


FIG. 1.—DWARF MILO, GROWN MAY 12 TO SEPTEMBER 14, 1911 (POTS 133 TO 138).
Water requirement, 833 ± 3 .



FIG. 2.—BLACKHULL KAFIR, GROWN MAY 12 TO SEPTEMBER 3, 1911 (POTS 139 TO 144).
Water requirement, 278 ± 5 .

The water requirement of the five varieties of sorghum based upon grain production is as follows:

Brown kaoliang.....	726± 12
Blackhull kafir.....	803± 26
White durra.....	806± 12
Dwarf milo.....	1,123± 57
Red Amber sorghum.....	1,494± 202

It is of interest to note in this connection that Red Amber sorghum is not a grain sorghum, but is grown exclusively for forage. Of the grain varieties tested Brown kaoliang requires the least water, while Dwarf milo requires the most, its water requirement being 55 per cent greater than that of the kaoliang. White durra and Blackhull kafir have practically the same water requirement—about 11 per cent higher than the kaoliang. It is probable that the water requirement based on grain is too high in the case of Dwarf milo, since some of the flowers were slightly damaged by a midge before it was discovered and killed.

The group as a whole shows a remarkably low water requirement whether based on dry matter or on grain. The sorghums most efficient in the use of water consume about 60 per cent of the water required by Kubanka wheat in the production of either dry matter or grain.

TABLE VIII.—Water requirement of different varieties of sorghum at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on —	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Red Amber, S. P. I. 17543 (<i>Andropogon sorghum</i>), May 12 to Sept. 4.....	127	279.5	44.2	81.1	16	1,835	290
	128	303.1	81.1	94.7	27	1,168	312
	129	297.9	31.0	85.2	10	2,748	286
	130	300.4	71.3	94.2	24	1,321	313
	131	334.9	108.4	96.9	32	893	289
	132	329.7	97.7	97.3	30	996	295
Mean.....						1,494± 202	298± 4
Dwarf milo, S. P. I. 24970 (<i>Andropogon sorghum</i>), May 12 to Sept. 4.....	133	222.9	70.9	75.5	31	1,065	338
	134	238.1	74.4	82.0	31	1,102	344
	135	232.0	99.5	74.3	43	746	320
	136	249.4	68.7	84.2	28	1,226	338
	137	251.5	63.0	83.3	25	1,322	331
	138	265.6	67.5	86.2	25	1,276	325
Mean.....						1,123± 57	333± 3
Blackhull kafir, S. P. I. 24975 (<i>Andropogon sorghum</i>), May 12 to Sept. 3.....	139	310.0	108.1	85.1	35	787	274
	140	333.5	125.0	90.1	38	720	270
	141	335.7	94.7	89.1	28	941	265
	142	290.9	99.9	87.0	36	871	310
	143	333.5	126.2	88.2	38	699	264
	144	335.6	120.2	96.4	36	802	287
Mean.....						803± 26	278± 5

TABLE VIII.—*Water requirement of different varieties of sorghum at Akron, Colo., in 1911—Continued.*

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
White durra, S. P. I. 24997 (<i>Andropogon sorghum</i>), May 12 to Sept. 5.....	145	292.8	111.6	92.2	38	826	315
	146	257.8	110.4	80.4	43	728	312
	147	300.1	118.9	94.8	40	797	316
	148	248.3	101.3	82.9	41	818	334
	149	309.0	124.5	99.4	40	798	322
	150	291.3	109.2	94.55	38	866	324
Mean.....						806±12	321±2
Brown kaoliang, S. P. I. 24993 (<i>Andropogon sorghum</i>), May 12 to Sept. 6.....	151	297.3	119.2	85.1	40	714	286
	152	247.2	102.6	76.5	42	746	309
	153	244.7	91.7	77.8	38	848	318
	154	223.5	90.4	66.0	40	730	295
	155	263.2	116.9	77.2	44	660	283
	156	229.3	105.6	69.4	46	657	302
Mean.....						726±12	301±3

WATER REQUIREMENT OF DIFFERENT VARIETIES OF MILLET.

Millet is a remarkable plant with respect to economy in the use of water, both in the production of dry matter and of grain. The two varieties tested at Akron, Colo., in 1911 (Table IX), namely, Kursk and German, gave, respectively, a water requirement for the dry matter produced of 287 ± 2 and 263 ± 15 , the latter figure being 44 per cent less than the water requirement of Kubanka wheat. The water requirement of the grain of Kursk millet was found to be 923 ± 40 , which is 23 per cent less than for Kubanka wheat and the lowest of any of the small grains measured. The ratios just given furnish an adequate explanation of the success of millet as a crop for semiarid regions. The amount of water required to produce a pound of rye (dry matter) would produce $2\frac{1}{2}$ pounds of millet, and the same ratio applies to the grain as well. The water economy exercised by millet in the production both of dry matter and of grain is a fact of the greatest significance to farmers in regions of limited rainfall.

TABLE IX.—*Water requirement of different varieties of millet at Akron, Colo., in 1911.*

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Kursk, S. P. I. 22420 (<i>Chaetochloa italica</i>), May 12 to Aug. 9.	157	159.7	45.5	47.3	29	1,040	296
	158	206.3	67.8	58.0	33	856	281
	159	234.9	73.3	67.1	31	916	286
	160	183.8	47.5	53.2	26	1,124	289
	161	229.0	81.2	64.6	36	796	282
	162	198.3	60.9	56.6	35	810	285
Mean.....						923±40	287±2
German, S. P. I. 26845 (<i>Chaetochloa italica</i>), May 12 to Aug. 21.	163	219.0	.....	49.5	.....	.....	226
	164	175.9	.....	48.1	.....	.....	273
	165	88.9	.....	21.8	.....	.....	245
	166	105.5	.....	25.5	.....	.....	242
	167	92.6	.....	34.2	.....	.....	369
	168	120.7	.....	26.5	.....	.....	220
Mean.....							263±15

WATER REQUIREMENT OF LEGUMES.

The legumes occupy an important position in dry-land agriculture, both in regard to their value as forage crops and from the standpoint of nitrogen fixation. The three legumes which have been most used in this connection are alfalfa, or lucern, Canada field peas, and sweet clover, and these species were tested at Akron, Colo., in 1911 as regards their water requirement. (Table X.)

The alfalfa made a splendid growth in the pots and three cuttings were made during the summer, the first on July 19 (Pl. IX, fig. 2), the second on September 18 (Pl. X, fig. 2), and the third on October 22. The first two crops attained their normal development, the plants being in full flower when the cuttings were made. The third cutting was made when the plants were about half grown. Considerable differences are, of course, to be expected in the water requirement of a crop grown at different seasons of the year, owing to changes in the climatic conditions. This is well illustrated in the case of the three crops of alfalfa, which gave the following water requirement:

Alfalfa:

First crop, May 13 to July 19.....	1,008±26
Second crop, July 19 to September 18.....	1,354±22
Third crop, September 18 to October 22	520±9
Crops combined, May 13 to October 22	1.068±16

The increase in the water requirement of the second crop is doubtless to be attributed to the hot weather of the latter part of July and of August, which came when this crop was making its most rapid growth. The third crop showed a very material reduction in the water requirement, due presumably to the cool weather of late September and of October.

The unusually high water requirement shown by alfalfa is not promising for the success of this plant as a dry-land crop. Alfalfa is far higher in its water requirement than any of the other plants tested, being practically double that of wheat and the other small grains, three times that of corn, and four times that of millet and sorghum. Too much emphasis should not, of course, be placed upon the determinations until they have been supported by the results of succeeding years; but, from the results of the experiments thus far, the writers question the practicability of growing alfalfa in regions of limited rainfall, when forage crops like sorghum and millet are available, which will produce the same amount of dry matter with one-fourth the amount of water.

If the growing of alfalfa is to be attempted in regions of limited rainfall, these experiments would indicate the advisability of a thin stand in rows or hills, with clean cultivation, thus securing for each plant the water supply of a relatively large soil mass. It would

appear that the crop could also be profitably limited to two cuttings, one made in the spring and the other in the fall, keeping the top growth small during the summer through pasturage or mowing. By following this procedure, the alfalfa would be growing most actively at seasons of the year when the crop shows its lowest water requirement. The writers are not aware that this plan has ever been given a practical test.

Sweet clover, owing to its adaptability and luxuriant habit of growth, is at present being tested in a number of localities regarding its value as a dry-land crop. While considered at first chiefly from the standpoint of its value as a green manure, it has also recently found considerable favor as a hay crop, stock gradually acquiring a taste for it in spite of the coumarin which at first proves so offensive.¹ From either standpoint the water requirement of sweet clover is an important consideration to the dry-land farmer. The experiments with this plant at Akron in 1911 gave a water requirement for sweet clover during the period from May 13 to July 19 of 675 ± 5 (Pl. IX, fig. 1). This period is identical with the period covered by the first alfalfa crop and shows the water requirement of sweet clover to be practically two-thirds that of alfalfa. A second crop (Pl. X, fig. 1) of sweet clover from the same roots grown from July 19 to September 21 gave a water requirement of 793 ± 12 , an increase over the first crop of 18 per cent, as compared with a corresponding increase of 34 per cent in the case of the second alfalfa crop. The sweet-clover plants failed to develop a third crop from the old roots. The season taken as a whole produced three crops of alfalfa with a water requirement of $1,068 \pm 16$ and two crops of sweet clover with a water requirement of 709 ± 9 . Sweet clover required 39 per cent less water than alfalfa for the production of the same amount of dry matter. In other words, $1\frac{1}{2}$ pounds of sweet clover were produced with the same amount of water required to produce 1 pound of alfalfa.

The Canada field pea in 1911 gave a water requirement of 800 ± 17 for the period from May 13 to August 7. It is thus intermediate between alfalfa and sweet clover in its water requirement. It is not strictly comparable with the results obtained with these two legumes, due to the different periods of growth. Moreover, the peas, through their recumbent habit of growth, were shaded to some extent by the pots and by other plants, which would tend to give a water requirement below the true value. From a comparison with the grain crops it would appear that the water requirement of field peas on a basis of the total dry matter produced is from 50 to 75 per cent greater than that of the small grains.

¹ See Westgate, J. M., and Vinal, H. N., "Sweet clover," U. S. Department of Agriculture, *Armenian Bulletin* 485, 1912.



FIG. 1.—SWEET CLOVER, GROWN MAY 13 TO JULY 19, 1911 (POTS 97 TO 102, POT 102 IN THE FOREGROUND).
Water requirement, 675 ± 5 .



FIG. 2.—GRIMM ALFALFA, GROWN MAY 13 TO JULY 19, 1911 (POTS 91 TO 96, POT 96 IN THE FOREGROUND).
Water requirement, 1008 ± 26 .



FIG. 1.—SWEET CLOVER, GROWN JULY 19 TO SEPTEMBER 21, 1911 (SECOND AND LAST CROP; POTS 97 TO 102).

Water requirement, 798 ± 12 .



FIG. 2.—GRIMM ALFALFA, GROWN JULY 19 TO SEPTEMBER 18, 1911.

Water requirement, 1354 ± 22 . Second crop; pots 91 to 95. Pot 96 is similar to the others, but being in use in physiological experiment is not included.



FIG. 3.—BUCKWHEAT, GROWN JUNE 10 TO SEPTEMBER 16, 1911 (POTS 173, AND 193 TO 196).

Water requirement, 578 ± 13 .

TABLE X.—The water requirement of legumes (alfalfa, Canada field peas, and sweet clover) at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirement based on—	
						Grain.	Dry matter.
		Grams.	Grams.	Kilos.	Per cent.		
Alfalfa, Grimm, S. P. I. 25006 (<i>Medicago sativa</i>), May 13 to July 19.....	91	86.0	.....	86.7	.....	.....	1,008
	92	69.5	.....	71.9	.....	.....	1,035
	93	76.2	.....	84.1	.....	.....	1,148
	94	82.2	.....	68.1	.....	.....	828
	95	66.9	.....	70.3	.....	.....	1,051
	96	86.8	.....	85.1	.....	.....	980
Mean.....							1,008±26
Second crop, July 19 to Sept. 18.....	91	77.2	.....	107.25	.....	.....	1,389
	92	85.4	.....	113.8	.....	.....	1,332
	93	84.4	.....	109.3	.....	.....	1,295
	94	75.2	.....	94.7	.....	.....	1,259
	95	71.9	.....	101.9	.....	.....	1,417
	96	113.0	.....	161.7	.....	.....	1,431
Mean.....							1,354±22
Third crop, Sept. 18 to Oct. 22.....	91	32.4	.....	16.65	.....	.....	514
	92	36.8	.....	19.5	.....	.....	530
	93	38.6	.....	18.1	.....	.....	469
	94	34.7	.....	17.6	.....	.....	507
	95	36.6	.....	20.0	.....	.....	546
	96	27.9	.....	15.4	.....	.....	552
Mean.....							520±9
Crops combined for season, May 13 to Oct. 22.....	91	195.6	.....	210.6	.....	.....	1,076
	92	191.7	.....	205.2	.....	.....	1,070
	93	196.2	.....	211.5	.....	.....	1,078
	94	192.1	.....	180.4	.....	.....	940
	95	175.4	.....	192.2	.....	.....	1,096
	96	227.4	.....	262.2	.....	.....	1,148
Mean.....							1,066±16
Sweet clover, S. P. I. 21216 (<i>Melilotus alba</i>), May 13 to July 19.....	97	141.0	.....	98.0	.....	.....	695
	98	144.7	.....	97.4	.....	.....	673
	99	160.8	.....	110.2	.....	.....	685
	100	155.3	.....	104.6	.....	.....	673
	101	158.0	.....	108.0	.....	.....	684
	102	185.4	.....	118.8	.....	.....	641
Mean.....							675±5
Second crop July 19 to Sept. 21.....	97	64.0	.....	52.7	.....	.....	823
	98	71.3	.....	52.1	.....	.....	730
	99	84.9	.....	68.4	.....	.....	506
	100	75.7	.....	63.3	.....	.....	836
	101	68.4	.....	55.0	.....	.....	804
	102	21.3	.....	16.15	.....	.....	758
Mean.....							793±12
Crops combined for season, May 13 to Sept. 21.....	97	205.0	.....	150.7	.....	.....	736
	98	216.0	.....	149.5	.....	.....	692
	99	245.7	.....	178.6	.....	.....	728
	100	231.0	.....	167.9	.....	.....	727
	101	226.4	.....	163.0	.....	.....	720
	102	206.7	.....	134.95	.....	.....	653
Mean.....							709±9
Canada field pea, S. P. I. 22637 (<i>Pisum sativum</i>), May 13 to Aug. 7.....	103	110.3	39.4	83.65	36	2,122	758
	104	96.6	36.7	73.3	38	1,997	759
	105	102.6	34.2	91.05	33	2,660	888
	106	94.6	38.4	71.75	47	1,899	758
	107	99.1	30.4	78.45	31	2,581	792
	108	73.2	29.8	62.05	41	2,062	848
Mean.....						2,218±100	800±17

WATER REQUIREMENT OF POTATOES AND SUGAR BEETS.

The Irish potato in the 1911 experiments at Akron, Colo., gave a water requirement practically identical with that of Kubanka wheat, namely, 448 ± 11 . (Table XI.) When calculated on the basis of the dry matter in the tubers alone the water requirement was 994 ± 38 . The potatoes made a perfectly normal growth in the cans and developed a fair crop of tubers of moderate size. (Pl. XI, fig. 4.)

Experiments with the sugar beet gave a water requirement for this plant of 377 ± 8 , or, when based upon the dry matter of the root alone, of 629 ± 18 . These plants also developed normally, although the roots were of only moderate size. (Pl. XI, fig. 5.) It is interesting to note that this crop agrees very closely with corn in its water requirement.

Potatoes and sugar beets have a comparatively low water requirement. As harvested and sold they contain a high percentage of water. The water requirement on the basis of the green weight of tubers and roots is therefore especially low, being 166 ± 4 for potatoes and 110 ± 3 for sugar beets.

TABLE XI.—Water requirement of potatoes and sugar beets at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Tubers or roots.	Water.	Tubers or roots.	Water requirement based on—	
						Tubers or roots.	Dry matter.
		<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>	<i>Per cent.</i>		
Potato, Irish Cobbler (<i>Solanum tuberosum</i>), June 10 to Sept. 19.	169	138.9	74.0	66.2	53	894	477
	170	151.9	74.0	66.4	49	897	438
	171	122.0	48.2	58.8	40	1,220	482
	172	159.2	69.8	68.2	44	977	428
	174	132.6	55.7	54.8	42	984	413
Mean.....						994 \pm 38	448 \pm 11
Sugar beet, Morrison - grown Kleinwanzleben (<i>Beta vulgaris</i>), June 10 to Sept. 19.....	175	153.6	89.7	65.0	58	725	423
	176	180.0	107.7	65.6	60	609	364
	177	207.7	128.5	71.7	62	558	345
	178	181.1	108.1	68.4	60	633	378
	179	141.6	82.5	55.4	58	671	391
	180	185.1	115.6	66.8	62	578	360
Mean.....						629 \pm 18	377 \pm 8

WATER REQUIREMENT OF RAPE.

Rape, which is used somewhat in dry farming as a pasture crop, was tested at Akron, Colo., for its water requirement during the period from August 18 to October 17, 1911. The crop was sown following oats, without the addition of fertilizer, and it is possible that the water requirement was somewhat increased by the lack of plant food. The water requirement obtained for this plant was 441 ± 12 (Table XII), as compared with a water requirement of 1,450 for a



FIG. 1.—*AMARANTHUS RETROFLEXUS* (PIGWEEED), GROWN AUGUST 5 TO SEPTEMBER 15, 1911 (POTS 7 TO 12; FERTILIZED).

Water requirement, 274 ± 3 .



FIG. 2.—*AMARANTHUS GRAECIZANS*, GROWN AUGUST 5 TO SEPTEMBER 15, 1911 (POTS 31 TO 36).

Water requirement, 277 ± 4 .



FIG. 3.—*SALSOLA FESTIFER* (RUSSIAN THISTLE), GROWN JUNE 10 TO SEPTEMBER 6, 1911 (POTS 181 TO 186).

Water requirement, 336 ± 5 .



FIG. 4.—IRISH COBBLER POTATOES, GROWN JUNE 10 TO SEPTEMBER 19, 1911 (FROM POTS 169 TO 174).

Water requirement, based on dry matter of tubers, 994 ± 38 ; based on total dry matter, 448 ± 11 .



FIG. 5.—MORRISON-GROWN KLEINWANZLEBEN SUGAR BEETS, GROWN JUNE 10 TO SEPTEMBER 19, 1911 (FROM POTS 175 TO 180).

Water requirement, based on dry matter of roots, 629 ± 18 ; based on total dry matter, 377 ± 8 .

new crop of Grimm alfalfa grown following barley during practically the same period. It would therefore appear that the water requirement of rape is only about one-third that of a new crop of alfalfa.

TABLE XII.—*Water requirement of rape at Akron, Colo., in 1911.*

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
		<i>Grams.</i>	<i>Kilos.</i>	
Rape (<i>Brassica napus</i>), Aug. 18 to Oct. 17.....	37	46.0	21.7	452
	38	18.1	8.7	481
	39	16.9	6.9	408
	40	27.3	12.25	449
	41	11.1	4.2	378
	42	14.5	6.95	479
Mean.....				441 ± 12

WATER REQUIREMENT OF WEEDS AND NATIVE PLANTS.

Four plants which grow without cultivation in eastern Colorado were used in the water-requirement experiments at Akron in 1911. (Table XIII.) Only one of these, *Artemisia frigida* (mountain sage) is a true native plant. It is abundant in the northern and central portion of the Great Plains. The other three plants are among the worst weed pests of this region. Two of these, the Russian thistle (Pl. XI, fig. 3) and *Amaranthus graecizans* (Pl. XI, fig. 2), are tumbleweeds, while the third, *Amaranthus retroflexus* (Pl. XI, fig. 1), is the ordinary redroot or pigweed, a common weed throughout the United States.

The water requirement based upon the production of dry matter is here summarized:

<i>Artemisia frigida</i>	765 ± 24
<i>Salsola pestifer</i>	336 ± 5
<i>Amaranthus retroflexus</i> (outside).....	356 ± 4
<i>Amaranthus retroflexus</i> (fertilized).....	274 ± 3
<i>Amaranthus graecizans</i>	277 ± 4
<i>Amaranthus graecizans</i> (outside).....	275 ± 7

Artemisia grew fairly well, somewhat better than in the native sod. Its water requirement is high—65 per cent higher than Kubanka wheat and 157 per cent higher than Red Amber sorghum. Only two of the cultivated crops tested, alfalfa and Canada field pea, have a higher water requirement. This is especially interesting, since *Artemisia frigida* from a morphological point of view would seem to be admirably adapted to a dry country. It is covered with a dense silvery pubescence, which protects it from sun and wind. This would tend to reduce the transpiration, but since the plant grows slowly it fails to show a high degree of efficiency in the use of water.

From the standpoint of water economy the weeds are decidedly efficient. For an equal production of dry matter the Russian thistle requires about the same amount of water as Dwarf milo, *Amaranthus retroflexus* (redroot) about the same quantity as Northwestern Dent corn, and *Amaranthus graecizans* (a tumbleweed) about the same quantity as Blackhull kafir.

Probably more water is needlessly lost through the growth of these and similar weeds than from any other cause. When soil moisture is available they make a rapid and luxuriant growth, and the water consumed by them is a complete loss, except in so far as they contribute organic matter to the soil. Sorghum, corn, or millet could take the place of these weeds with no greater consumption of soil moisture.

One set of pots of *Amaranthus retroflexus* was fertilized. This set showed clearly the effect of the additional amount of plant food, especially nitrogen, the plants being unusually luxuriant (Pl. X, fig. 1) and of a dark-green color. The water requirement of this set was 23 per cent lower than that of a similar but unfertilized set grown in soil which had just produced a heavy crop of wheat. *Amaranthus graecizans* was used to check the effect of the shelter upon the water requirement. Six pots were grown in a freely exposed position outside the shelter, and six inside the shelter. The two sets agreed as to their water requirement.

TABLE XIII.—Water requirement of weeds and native plants at Akron, Colo., in 1911.

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.	Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
		Grams.	Kilos.				Grams.	Kilos.	
<i>Salsola pestifer</i> , June 10 to Sept. 6.....	181	193.0	68.8	356	<i>Artemisia frigida</i> , June 10 to Sept. 21.....	187	17.9	14.8	827
	182	178.5	58.6	328		188	26.5	24.0	658
	183	144.0	50.2	349		189	44.4	31.3	705
	184	150.3	51.3	341		190	16.2	14.35	896
	185	164.4	51.6	314		191	30.2	22.45	743
	186	167.6	54.9	328		192	51.9	39.95	773
Mean.....				336±5	Mean.....				765±24
<i>Amaranthus retroflexus</i> , Aug. 5 to Sept. 15 (outside the shelter).....	1	96.0	33.7	351	<i>Amaranthus retroflexus</i> , Aug. 5 to Sept. 15 (inside the shelter), fertilized.....	7	133.4	37.0	277
	2	46.9	17.9	382		8	89.0	26.0	292
	3	72.2	25.75	357		9	134.6	36.7	273
	4	66.5	23.5	353		10	136.4	36.8	270
	5	98.9	35.1	355		11	116.8	30.9	265
	6	88.0	29.5	335		12	128.7	34.0	264
Mean.....				356±4	Mean.....				274±3
<i>Amaranthus graecizans</i> , Aug. 5 to Sept. 15 (inside the shelter).....	31	35.3	10.0	283	<i>Amaranthus graecizans</i> , Aug. 5 to Sept. 15 (outside the shelter).....	79	70.2	17.3	246
	32	29.2	8.1	277		80	45.9	11.5	251
	33	69.1	18.4	266		81	62.9	17.06	271
	34	24.9	6.5	261		82	55.3	16.8	304
	35	37.8	11.35	300		83	51.6	15.2	296
	36	27.1	7.5	277		84	69.7	19.15	275
Mean.....				277±4	Mean.....				275±7

WATER REQUIREMENT OF CROPS GROWN OUT OF SEASON.

After the first crop of small grains was removed from the cans at Akron, Colo., in 1911, some of the pots were planted to a second crop. The results obtained from this second crop when the plants were grown out of their normal season are given in Table XIV. None of these plants reached maturity and the amount of dry matter harvested was small. The water requirement of alfalfa was 36 per cent more and that of sweet clover 84 per cent more than for the normal crop. Barley and wheat were 3 and 8 per cent higher than when grown in season. Canada field peas, oats, and spring rye had a much lower water requirement than when grown in season, the decrease being 20 per cent for Canada field peas, 26 per cent for oats, and 35 per cent for spring rye. The lower water requirement of these plants is of interest, since they are what might be called cool-weather crops and make a better growth under this condition than do other crops less adapted to cool weather. The results suggest that during late fall and early spring, rye, oats, and Canada field peas are exceptionally efficient plants, giving a large amount of growth in proportion to the water consumed and that during the warmer portion of the year they are relatively inefficient.

TABLE XIV.—*Water requirement of crops grown out of season at Akron, Colo., in 1911.*

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.	Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
		<i>Grams.</i>	<i>Kilos.</i>				<i>Grams.</i>	<i>Kilos.</i>	
Wheat, Kunkanka (G. I. 1440), Aug. 9 to Oct. 22.....	25	8.6	4.5	523	Sweet clover (S. P. I. 21216), Aug. 3 to Oct. 22.....	74	44.6	60.85	1.364
	26	10.6	7.4	698		75	52.0	61.0	1.173
	27	18.8	7.8	415		76	37.9	50.7	1.338
	28	9.1	4.3	477		77	43.6	52.1	1.195
	29	14.8	6.05	409		78	35.8	52.2	1.458
	30	16.1	8.15	506					
Mean.....				505±27	Mean.....				1,306±31
Oats, Sixty-Day (G.I.165), Aug. 16 to Oct. 22.....	55	27.1	10.95	404	Alfalfa, Grimm (S. P. I. 25695), Aug. 3 to Oct. 22.....	67	35.4	52.05	1.470
	56	30.3	15.8	522		68	27.6	38.0	1.376
	57	31.6	13.2	418		69	29.4	41.55	1.413
	58	32.4	15.15	468		70	22.6	33.2	1.469
	59	21.5	9.4	437		71	29.5	46.1	1.563
Mean.....				450±11	Mean.....	72	33.3	46.95	1.410
Barley, Beldi (G. I. 190), Aug. 3 to Oct. 22.....	61	37.2	23.7	637	Canada field pea (S. P. I. 22637), Aug. 9 to Oct. 22.....	103	52.1	30.35	582
	62	55.9	31.1	556		104	34.0	20.2	594
	63	38.7	22.7	586		105	54.1	33.8	625
	64	50.0	25.0	800		106	44.9	30.5	679
	65	53.6	29.85	557		107	49.1	32.6	664
	66	52.1	26.75	513		108	47.9	32.25	673
Mean.....				558±13	Mean.....				636±14
Rye, spring (G. I. 73), Aug. 9 to Oct. 22.....	85	50.0	26.5	530					
	86	29.3	14.9	508					
	87	67.7	30.7	454					
	88	5.9	2.7	468					
	89	18.5	8.35	451					
	90	38.9	16.8	432					
Mean.....				472±12					

TABLE XIV.—*Water requirement of crops grown out of season at Akron, Colo., in 1911—Continued.*

SUMMARY OF MEANS.

Crop.	Period of growth.	Pot Nos.	Water requirement based on dry matter.	Crop.	Period of growth.	Pot Nos.	Water requirement based on dry matter.
Wheat, Kubanka (G. I. 1440).	Aug. 9-Oct. 22	25-30	505±27	Rye, spring.....	Aug. 9-Oct. 22	85-90	472±12
Oats, Sixty-Day.	Aug. 16-Oct. 22	55-60	450±11	Alfalfa, Grimm	Aug. 3-Oct. 22	67-72	1,450±19
Barley, Beldi.	Aug. 3-Oct. 22	61-66	558±13	Sweet clover....	Aug. 3-Oct. 22	74-78	1,306±31
				Canada field pea.	Aug. 9-Oct. 22	108-108	636±14

SUMMARY OF WATER-REQUIREMENT MEASUREMENTS IN COLORADO, 1911.

Table XV shows that the water requirement of different varieties of the same crop differs but little as compared with the variation in the water requirement of different crops. The water requirement of the most efficient variety is 88 per cent of that of the least efficient in the case of wheat; oats, 94 per cent; barley, 97 per cent; millet, 92 per cent; corn, 76 per cent; and sorghum, 84 per cent.

A summary of the water requirement of the different crops grown at Akron, Colo., in 1911 is given in Table XV. In cases where several varieties of the same crop have been tested, the mean water requirement of the different varieties is given; and where several cuttings were made during the season, as with alfalfa and sweet clover, the mean for the season is given. It will be seen that wheat occupies a central position in this series, falling next to barley, the water requirement of which is very nearly the geometric mean of the limits of the series.

TABLE XV.—*Summary of the water requirement of crops grown at Akron, Colo., in 1911.*

Crop.	Period of growth.	Pot Nos.	Water requirement based on—		Remarks.
			Grain.	Dry matter.	
Wheat:	May 13 to Aug. 2	1-6, 199-204	1,191±14	468±8	Fertilized.
Kubanka.....	do.	7-12	1,184±36	422±6	
Bluestem.....	May 13 to Aug. 7	13-18	1,786±60	531±5	
Galgalos.....	May 13 to Aug. 1	19-24	1,245±13	496±4	
Spring Ghirka.....	May 13 to Aug. 4	25-30	1,382±43	506±3	
Emmer.....	do.	79-84	1,180±42	534±14	
Oats:					
Sixty-Day.....	May 13 to Aug. 2	31-36	1,383±30	605±5	
Canadian.....	May 13 to Aug. 12	37-42	2,204±140	598±14	
Burt.....	do.	43-48	1,800±57	639±7	
Swedish Select.....	May 13 to Aug. 7	49-54	1,632±35	615±7	
Barley:					
Hannchen.....	May 13 to Aug. 12	55-60	1,134±27	527±8	
Beldi.....	May 13 to Aug. 1	61-66	1,155±18	543±2	
White Hull-less.....	May 13 to July 31	67-72	1,475±40	542±3	
Beardless.....	May 13 to Aug. 1	74-78	1,210±38	544±9	
Rye:					
Spring.....	May 13 to Aug. 5	85-90	2,215±37	724±7	

TABLE XV.—Summary of the water requirement of crops grown at Akron, Colo., in 1911—Continued.

Crop.	Period of growth.	Pot Nos.	Water requirement based on—		Remarks.
			Grain.	Dry matter.	
Millet:					
Kursk.....	May 12 to Aug. 9..	157-162	923±40	257±2	
German.....	May 12 to Aug. 21..	163-168		263±15	
Buckwheat.....	June 10 to Sept. 16..	168-196, 173	1,037±33	578±13	
Corn:					
Northwestern Dent.....	May 24 to Aug. 23..	109-114	2,040±340	368±10	
Iowa Silvermine.....	May 24 to Sept. 4..	115-120		420±3	
Esperanza.....	May 12 to Aug. 21..	121-126		319±5	
Sorghum:					
Red Amber.....	May 12 to Sept. 4..	127-132	1,494±200	296±4	
Dwarf mfls.....	do.....	133-138	1,123±57	333±3	
Blackhull kafir.....	May 12 to Sept. 3..	139-144	803±26	278±5	
White durra.....	May 12 to Sept. 5..	145-150	806±12	321±2	
Brown kaoliang.....	May 12 to Sept. 6..	151-156	726±12	301±3	
Alfalfa:					
Grimm.....	May 13 to July 19..	91-96		1,008±26	
	July 19 to Sept. 18..	91-96		1,354±22	
	Sept. 18 to Oct. 22..	91-96		520±9	
	May 13 to Oct. 22..	91-96		1,068±16	
Sugar beet:					
Morrison-grown Kleinwanzleben.....	June 10 to Sept. 19..	175-180	629±18	377±8	Combined for season.
			110±3		Based on dry matter and dry roots.
Canada field pea.....	May 13 to Aug. 7..	103-108	2,218±100	800±17	Based on green roots.
Rape.....	Aug. 18 to Oct. 17..	37-42		441±12	
	May 13 to July 19..	97-102		675±5	
Sweet clover.....	July 19 to Sept. 21..	97-102		798±12	
	May 13 to Sept. 21..	97-102		709±9	
Potato:					
Irish Cobbler.....	June 10 to Sept. 19..	169-172, 174	994±38	448±11	Combined for season.
			166±4		Based on dry matter and dry tubers.
Amaranthus retroflexus.....	Aug. 5 to Sept. 15..	1-6		356±4	Based on green tubers.
		7-12		274±3	Outside the shelter.
Amaranthus gracilis.....	do.....	31-36		277±4	Fertilized.
		79-84		275±7	Inside the shelter.
Artemisia frigida.....	June 10 to Sept. 21..	187-192		765±24	Outside the shelter.
Salsola pestifer.....	June 10 to Sept. 6..	181-186		336±5	

SUMMARY OF WATER REQUIREMENT OF CROPS BASED UPON THE MEANS OF DIFFERENT VARIETIES.

Crop.	Water requirement.	Relative water requirement compared with wheat.	Crop.	Water requirement.	Relative water requirement compared with wheat.
Alfalfa.....	1,068	211	Wheat.....	507	100
Canada field pea.....	800	158	Potato.....	448	88
Artemisia (native).....	765	151	Rape.....	441	87
Spring rye.....	724	143	Sugar beet.....	377	74
Sweet clover.....	709	140	Corn.....	369	73
Oats.....	614	122	Weeds.....	322	63
Buckwheat.....	578	114	Sorghum.....	306	60
Barley.....	539	106	Millet.....	275	54

Millet, sorghum, and corn have a water requirement ranging from 275 to 370, the small grains from 510 to 700, and the legumes from 710 to 1,070. Sorghum and corn are long-season crops, making their best growth during hot, dry weather. The small grains are short-season crops, which grow well during cool weather. Notwithstanding these facts, the water requirement of the small grains is higher than that of sorghum and corn.

Of the crops which produce grain, millet and sorghum consume about one-half the amount of water required by oats, barley, and wheat for the production of an equal quantity of dry matter.

Forage crops cover the whole range in water requirement, millet producing almost four times as much dry matter with the same amount of water as alfalfa, three times as much as spring rye, and two and one-half times as much as sweet clover.

The water requirement of the introduced weeds is comparatively low, while the native plant *Artemisia frigida* has a relatively high water requirement.

The water requirement of millet and sorghum based on grain production is about one-half that of oats and about two-thirds that of wheat and barley.

DETERMINATION OF THE WATER REQUIREMENT OF CROPS IN THE FIELD.

The determination of the water requirement of crops growing in the field under normal conditions is attended with a good deal of uncertainty, owing to the fact that the evaporation from the soil surface is not known. The actual change in the soil-moisture content during the experiment can be measured, and the probable error of these measurements can be calculated; but these measurements necessarily include the evaporation from the soil surface, which should not, of course, be charged to the water requirement of the plant under investigation. A second element of uncertainty arises in connection with the precipitation. The total precipitation during the growth period is usually included in the determination of the water requirement. It is evident that this may give values which are entirely too high, particularly in regions of torrential rainfall, owing to the run-off which occurs during such rains. The writers have endeavored to avoid this error in their field measurements by making daily determinations of the soil-moisture content and charging to the crop only that portion of the rainfall which actually penetrates the soil, as shown by the differences in the daily soil-moisture determinations before and after each rain. This will be referred to in more detail later.

WATER REQUIREMENT OF KUBANKA WHEAT GROWN UNDER FIELD CONDITIONS IN COLORADO.

FIELD EXPERIMENTS IN 1910.

A one-half acre plat of Kubanka wheat (G. I. 1440), grown on land which had raised a cultivated crop the previous year, was used in the 1910 experiments at Akron, Colo. The conditions were not particularly favorable, owing to the lack of uniform distribution of the moisture in the soil, as is often the case in regions of limited rainfall.

The initial moisture content was determined to a depth of 6 feet by a series of samples taken on six consecutive days during the period of germination, each sample consisting of a composite of three cores. These samples were taken in 1-foot sections with a soil-sampling tube, and the moisture content of the different sections was determined separately, for the purpose of checking their uniformity. A similar series of daily determinations was taken during the six days immediately preceding harvest. The crop at this time showed a lack of uniformity, owing to the inequality of the moisture supply in different parts of the plat. Each daily determination was therefore made in triplicate, one sample being taken in the best wheat, a second in wheat of medium quality, and the third in the poorest wheat. Each sample consisted of three cores, as before. The average moisture content of these 18 samples, each sample consisting of three cores extending to a depth of 6 feet, was taken to represent the final moisture content of the soil.

The season of 1910 was exceptionally dry, the total precipitation during the interval between the initial and final sampling amounting to only 1.09 inches. This was chiefly confined to three rains of 0.31, 0.30, and 0.38 of an inch. The increase in soil-moisture content, as shown by the difference in the daily samples taken immediately preceding and following each rain, was added to the loss of water represented by the difference between the initial and final soil-moisture determinations. The total represents the amount of water used by the crop expressed as a percentage of the dry weight of the soil. The apparent specific gravity or weight of the soil per unit volume was determined from a large number of samples, and from this the amount of water lost per unit area was calculated.

The amount of dry matter on the unit area was determined by harvesting three quadrates of grain, each 10 square yards in area, one being chosen from the best wheat, one from wheat of medium quality, and one from the poorest. Each sample was dried at 110° C. and the total dry weight and the weight of the grain determined. The mean of the three determinations in each case was taken to represent the average production of dry matter and grain on the plat.

From these determinations the following data were obtained for Kubanka wheat under field conditions in 1910:

Water requirement, dry matter.....	570
Water requirement, grain.....	1, 900
Dry matter produced per acre.....pounds..	2, 315
Grain produced per acre (11.7 bushels).....do....	700
Water used per acre.....tons..	615
Rainfall equivalent of water used.....inches..	6
Actual rainfall during period.....do....	1
Stored precipitation.....do....	5

In connection with the stored precipitation it should be stated that heavy rains, amounting in all to about 5 inches, occurred early in the season, before and soon after the crop was planted and before the initial moisture determinations were made. The stored precipitation should not therefore be considered as having all been carried over from the preceding fall.

FIELD EXPERIMENTS IN 1911.

A similar series of determinations was also carried on with Kubanka wheat during the season of 1911. In this work duplicate samples were taken every second day to a depth of 6 feet in 1-foot sections, each sample consisting of a composite of two cores. The wheat was grown on summer-fallowed land, but owing to the drought of the preceding season the initial water supply was limited, and while the precipitation during the growing period considerably exceeded that of the preceding year the yield was less. The precipitation during the growing season amounted to 3.7 inches, which came mainly in five rains of 0.92, 0.72, 0.64, 0.76, and 0.35 of an inch. Owing to the dry weather, the Russian thistle made a considerable growth on the plat before the wheat shaded the ground. The Russian thistle on the quadrat harvested was also cut and weighed, and a correction was made for the amount of water used by this plant, assuming its water requirement to be the same as that found in our pot experiments. The total rainfall during the growing period, accounted for by the soil-moisture determinations made before and after each rainfall, amounted to 3.15 inches.

A statement of the water requirement and other data connected with the production of the 1911 Kubanka wheat crop under field conditions follows:

Water requirement, dry matter.....	862
Water requirement, grain.....	2,380
Dry matter produced per acre..... pounds..	1,765
Grain produced per acre (10.7 bushels)..... do....	645
Water used per acre..... tons..	761
Rainfall equivalent of water used..... inches..	6.7
Rainfall accounted for from daily sampling..... do....	3.15
Stored precipitation..... do....	3.55

The water requirement of wheat grown under field conditions in 1911 is much higher than that obtained from the pot experiments or under field conditions during 1910. The writers are inclined to the opinion that this discrepancy is due to the assumption that the seasonal rainfall, or particularly that part of it which penetrates the soil, is as available to the crop as that already stored in the ground. Crops like wheat reduce the moisture content of the surface foot of soil to the wilting coefficient (Briggs and Shantz, 1912), or below, during the early stages of their growth. If during

this period rains do not replenish the moisture supply of the surface foot, the roots in this area soon become inactive. Consequently, subsequent rains which do not penetrate beyond the surface foot appear to be of much less value than an equal amount of water in the neighborhood of the active roots, owing to the fact that the water from the rain is largely lost through evaporation before the plants can establish new rootlets to take advantage of this temporary water supply. That a condition of this kind exists in the Great Plains is indicated by the fact that the water requirement of the wheat crops of 1910 and 1911, when the seasonal precipitation is ignored, agrees within the limits of experimental error with each other and with the water requirement of Kubanka wheat as determined in the pot experiments. The comparison may be made from the data given in Table XVI.

TABLE XVI.—*Comparison of the water requirement of Kubanka wheat crops grown under field conditions and in pots, at Akron, Colo.*

Class of experiments.	Water requirement—			
	Including rainfall during growth—		Excluding rainfall during growth—	
	Based on dry matter.	Based on grain.	Based on dry matter.	Based on grain.
Field experiment, 1910.....	700	2,315	496	1,780
Field experiment, 1911.....	862	2,380	466	1,614
Pot experiment, 1911.....			408±8	1,196±15

DETERMINATION OF AVAILABLE PRECIPITATION BY DAILY SOIL SAMPLING.

It is of interest to compare the increase in soil-moisture content found by sampling in the experiments just described with the actual rainfall as measured by the rain gauge. The results for the principal rains which occurred during the growing seasons of the two years are given in Table XVII. For convenience in comparison, the increase in soil moisture has been expressed in terms of inches of rainfall. The penetration refers to the thickness of the layer of moist soil at the time of the first sampling following the rain.

TABLE XVII.—*Comparison of the amount of rainfall with the increase in soil water as determined by daily sampling at Akron, Colo., in 1910 and 1911.*

Date.	Precipitation—		Depth of penetration.	Date.	Precipitation—		Depth of penetration.
	Actual.	Found by sampling.			Actual.	Found by sampling.	
1910.	Inches.	Inches.	Inches.	1911.	Inches.	Inches.	Inches.
June 24.....	0.31	0.86		May 27-28.....	0.92	1.00	
July 1.....	.30	.34		June 16.....	.65	.80	6.5
July 4.....	.38	.18		June 25.....	.64	.55	6.0
				July 12.....	.76	.55	4.5

In 1910, samples were taken daily and each determination is based upon the mean of nine cores. In 1911, samples were taken every second day, four cores being used in each determination. When rain fell, additional samples were taken as soon as the rain had ceased. The measurements in Table XVII serve to give an idea of the accuracy which was attained by this method. No heavy torrential rains occurred in either year during the growing period, so that the determinations did not include measurements made under the most unfavorable conditions for the absorption of the rainfall. Although the daily samples need to be taken only to a depth of 2 feet for the purpose of determining the amount of rainfall which has been absorbed, it is necessary to include a number of cores in each determination to insure a reliable value, and the determinations represent in the aggregate considerable work. In regions free from torrential rains or where the measurements can be carried on during the dry season it appears practicable from the results in Table XVII to restrict the measurements to the initial and final determinations and to add to the water lost, as calculated by these measurements, the intervening rainfall as measured by the rain gauge. In regions of torrential rains, however, this procedure would be attended with great uncertainty, due to the run-off and to rain-gauge errors, so under such circumstances the writers believe daily sampling or sampling every second day, with additional sampling following each rain, to be necessary. Even this method probably gives a water requirement which is somewhat high, due to the fact that plant roots in the more advanced stages of growth are often inactive in the first 6 inches of the surface soil, which in dry periods is the only portion moistened except by the heaviest rains.

The daily moisture curves for 1910 and 1911 give no indication that the rains penetrated the second foot. While the number of determinations is too small to warrant definite conclusions on this subject, the experiments so far indicate strongly that rains of even 0.6 and 0.8 inch are of little value to a wheat crop in the Great Plains, provided the preceding weather has been so dry that the plants have exhausted all available water to a depth of a foot or more, so that all the active rootlets are confined to lower depths.

WATER REQUIREMENT AS AFFECTED BY CLIMATIC CONDITIONS.

The variation in the water requirement of a given crop in a given locality from year to year may be looked upon as a measure of the integrated result of the climatic factors which are constantly varying during the period of growth. In attempting to effect a correlation between the water requirement and the intensity of the climatic factors as expressed by daily measurement, one is at once confronted with the difficulty arising from the fact that the plant during a

large part of its growing period is steadily increasing in size and weight. As a result, severe climatic conditions have a far less influence upon the water requirement in the early stages of growth, when the leaf area is small, than during the period when the crop is developing dry matter most rapidly. Therefore, in order to make an effective comparison of the water requirement with climatic conditions it is necessary to weigh the climatic factors at various stages of the growth of the crop, according to the dry weight of the crop at these chosen stages.

A summary of the climatic conditions prevailing at each station in the Great Plains where water-requirement experiments were made in 1910 and 1911 is given in Table XVIII.¹ The daily measurements are summarized in 5-day periods, and the table shows the average daily temperature during this period, the mean of the maximum temperatures, the mean of the minimum temperatures, and the extreme temperatures during the period; the total rainfall and the total evaporation from a free water surface, as well as the average wind velocity, are also given.

TABLE XVIII.—*Climatic data for Akron, Colo., and Dalhart, Tex., in 1911.*

OBSERVATIONS AT AKRON, COLO.

Date.		Mean soil tem- per- ture.	Air temperature (°F.).					Precipitation.	Evapora- tion.	Wind velocity per hour.
Month.	Days (in- clusive).		Average—			Maxi- mum.	Mini- mum.			
			Of means.	Of max- ima.	Of min- ima.					
		° F.						Inches.	Inches.	Miles.
April.....	1 to 5	46	64	29	77	24	0.16	0.98	8.5	
	6 to 10	44	59	26	67	16	0	.93	8.8	
	11 to 15	51	41	57	23	69	19	0	1.18	7.0
	16 to 20	58	50	67	29	69	25	Trace.	1.12	7.7
	21 to 25	58	51	62	40	81	39	1.74	1.02	10.8
	26 to 30	53	49	62	36	75	20	.73	.62	11.6
May.....	1 to 5	48	44	55	34	68	28	.03	.34	9.4
	6 to 10	64	60	76	43	87	30	.04	1.17	8.5
	11 to 15	66	64	80	45	84	35	Trace.	1.52	10.2
	16 to 20	65	58	76	42	91	36	.16	1.72	11.4
	21 to 25	65	64	78	45	91	34	0	1.37	8.9
	26 to 31	64	59	73	47	85	36	.92	1.20	9.7
June.....	1 to 5	74	70	87	50	90	47	Trace.	1.68	8.2
	6 to 10	75	69	88	49	93	43	Trace.	1.64	7.3
	11 to 15	79	70	90	50	96	45	.07	1.62	5.9
	16 to 20	72	67	78	54	90	48	.65	1.30	8.0
	21 to 25	81	73	91	55	92	51	.66	1.67	6.3
	26 to 30	79	73	92	58	98	50	.10	1.85	8.5
July.....	1 to 5	80	71	88	57	93	54	.12	1.70	7.8
	6 to 10	84	73	90	56	94	46	.01	1.72	7.3
	11 to 15	80	70	86	56	93	54	.77	1.69	7.5
	16 to 20	75	67	80	55	86	53	.44	.88	6.4
	21 to 25	79	68	84	52	92	46	0	1.69	7.3
	26 to 31	83	73	90	56	95	49	Trace.	2.09	6.4

¹ These data form a part of the climatic measurements made in cooperation with the Office of Dry-Land Agriculture, Bureau of Plant Industry, at each of the dry-land stations.

TABLE XVIII.—*Climatic data for Akron, Colo., and Dalhart, Tex., in 1911—Continued.*

OBSERVATIONS AT AKRON, COLO.—Continued.

Date.		Mean soil tem- pera- ture.	Air temperature (°F.).					Precipi- tation.	Eva- poration.	Wind velocity per hour.
Month.	Days (in- clusive).		Average—			Maxi- mum.	Mini- mum.			
			Of means.	Of max- ima.	Of min- ima.					
August.....	1 to 5	75	67	87	53	91	48	<i>Inches.</i> .29	<i>Inches.</i> 1.02	<i>Miles.</i> 10.1
	6 to 10	83	73	91	57	99	40	.82	1.87	7.4
	11 to 15	80	74	89	61	96	56	.19	1.35	5.9
	16 to 20	83	73	92	58	97	53	0	1.50	7.6
	21 to 25	71	61	74	48	84	41	Trace.	1.39	9.6
	26 to 31	73	67.	85	50	94	45	0	1.80	8.3
September.....	1 to 5	73	67	86	53	94	49	1.75	1.63	7.4
	6 to 10	73	64	79	52	87	49	.16	1.04	6.9
	11 to 15	75	70	86	57	95	52	.12	1.27	5.8
	16 to 20	66	59	75	44	86	39	0	1.44	8.9
	21 to 25	67	61	80	44	88	36	0	1.00	6.0
	26 to 30	66	61	76	49	85	48	.37	.80	6.8

OBSERVATIONS AT DALHART, TEX.

April.....	1 to 5	54	54	72	41	84	33	0.06	1.04	9.5
	6 to 10	53	49	63	36	76	30	0	1.24	10.7
	11 to 15	57	50	66	33	79	25	0	1.45	9.2
	16 to 20	60	57	74	40	82	33	0	1.45	8.4
	21 to 25	58	55	65	45	81	43	.42	.80	9.7
	26 to 30	61	57	74	43	83	30	.11	1.59	11.8
May.....	1 to 5	62	55	70	47	80	36	0	1.03	10.9
	6 to 10	70	68	88	51	93	36	.05	2.21	12.7
	11 to 15	64	62	77	54	84	48	2.14	1.42	9.4
	16 to 20	66	65	80	51	89	43	.09	2.29	13.3
	21 to 25	69	70	84	52	92	41	0	1.59	10.1
	26 to 31	68	68	81	57	90	52	1.09	1.38	8.7
June.....	1 to 5	74	77	92	59	97	54	0	1.82	9.0
	6 to 10	79	77	93	59	96	53	0	2.01	8.8
	11 to 15	80	76	90	57	95	53	0	1.80	6.5
	16 to 20	81	74	89	58	96	56	.09	1.87	7.0
	21 to 25	82	82	98	62	105	59	0	2.41	8.7
	26 to 30	.....	80	93	65	95	58	.19	2.47	12.6
July.....	1 to 5	.....	81	98	63	97	61	0	2.11	9.2
	6 to 10	.....	78	92	66	94	64	.17	1.85	9.7
	11 to 15	.....	75	87	63	96	61	.59	1.24	6.4
	16 to 20	.....	75	89	64	95	61	2.65	1.16	6.3
	21 to 25	.....	72	83	60	93	54	.11	1.12	8.4
	26 to 31	.....	75	92	62	95	59	.13	2.23	7.4
August.....	1 to 5	.....	74	89	62	93	56	.03	1.71	8.2
	6 to 10	.....	82	99	63	104	61	0	2.35	7.7
	11 to 15	.....	82	95	65	101	61	0	1.95	5.9
	16 to 20	.....	83	98	66	102	64	0	2.18	6.4
	21 to 25	.....	64	74	55	100	52	1.66	1.22	7.6
	26 to 31	.....	68	82	53	93	49	.18	1.48	6.7
September.....	1 to 5	.....	74	91	56	94	55	0	1.56	8.8
	6 to 10	.....	71	85	58	93	55	.06	1.16	6.4
	11 to 15	.....	77	93	61	96	58	.10	1.53	6.4
	16 to 20	.....	67	86	50	94	44	0	1.65	7.1
	21 to 25	.....	74	91	57	95	43	0	1.46	7.7
	26 to 30	.....	72	87	61	93	58	.42	1.41	8.4

The evaporation from a free water surface is the simplest factor that can be chosen as a basis for correlation with the water requirement, since both measurements are obviously influenced by temperature, humidity, and wind velocity, although not necessarily to the same degree. Table XIX gives the water requirement of wheat and

sorghum grown in Colorado and Texas during 1910 and 1911, together with the total evaporation from a free water surface during the growing period, computed from the data given in Table XVIII and from corresponding data for 1910. Table XIX also gives the ratio of the water requirement of the crop grown in Texas to the Colorado crop for each year, together with the corresponding evaporation ratio during the growing period. It will be noted from this table that the water-requirement ratio of sorghum is less in each case than the corresponding evaporation ratio, while the water-requirement ratio of wheat is higher in each case than the corresponding evaporation ratio. Thus, while the figures indicate an increased water requirement accompanying an increase in evaporation from a free water surface, the effect is very much greater with wheat than with sorghum. The Panhandle of Texas is recognized as more suitable for raising sorghum than for raising wheat, and these determinations suggest that climatic factors other than evaporation, such as temperature, for example, may be responsible for this. However, it should be kept in mind that the amount of evaporation given in the tables refers to that taking place during the whole period of growth, while the evaporation during the period of active growth would undoubtedly have more influence upon the water requirement than during the initial and final stages.

TABLE XIX.—*Comparison of the relative evaporation and of the relative water requirement in the Great Plains in 1910 and 1911.*

Station.	Year.	Crop.	Growing period.	Evaporation.		Water requirement.	
				Actual.	Relative.	Actual.	Relative.
Akron, Colo.	1910	Wheat..	{Apr. 18 to Aug. 2.....	27.7	100	664	100
Amarillo, Tex.			{Apr. 5 to July 19.....	34.0	123	853	128
Akron, Colo.	1910	Sorghum	{May 25 to Sept. 28.....	33.0	100	356	100
Amarillo, Tex.			{May 10 to Aug. 28.....	37.7	114	359	101
Akron, Colo.	1911	Wheat..	{May 13 to Aug. 2.....	24.8	100	468	100
Dalhart, Tex.			{Apr. 25 to July 18.....	28.5	115	673	143
Akron, Colo.	1911	Sorghum	{May 12 to Sept. 4.....	35.0	100	298	100
Dalhart, Tex.			{May 14 to Sept. 12.....	41.9	120	313	105

A summary of the evaporation measurements in Colorado and in the Panhandle of Texas for the April to September period is given in Table XX as a basis for comparing the years of 1910 and 1911 with the normal evaporation of those regions. It will be noted that June and July, 1910, at Amarillo were exceptionally severe months. The season of 1911 at Dalhart was normal, so far as the evaporation was concerned, while at Akron the year 1910 was slightly below and 1911 slightly above the normal.

TABLE XX.—*Monthly evaporation at Akron, Colo., and at Amarillo and Dalhart, Tex., for the period from April to September, inclusive, 1907 or 1908 to 1911.*

Station.	Year.	Evaporation.							Normal.
		April.	May.	June.	July.	August.	September.	Seasonal total.	
Akron, Colo.....	1908	4.74	7.70	8.64	8.47	7.83	8.55	45.93	45.18
	1909	4.74	6.82	7.00	9.40	8.53	5.86	42.35	
	1910	6.39	5.79	8.71	9.78	7.14	5.81	43.62	
	1911	5.85	7.32	9.76	9.77	8.93	7.18	48.81	
Amarillo, Tex.....	1907	6.36	8.04	9.59	10.68	9.40	7.91	51.98	54.02
	1908	7.31	9.28	10.38	8.07	8.57	6.77	50.38	
	1909	8.14	10.02	10.34	9.97	9.66	8.42	56.55	
	1910	8.50	8.03	12.00	12.18	8.80	9.10	58.61	
	1911	7.36	10.10	11.48	7.48	8.89	7.28	52.59	
Dalhart, Tex.....	1908	6.93	10.93	12.08	9.19	9.90	7.95	56.98	58.32
	1909	8.53	9.90	10.89	11.69	10.56	7.85	59.42	
	1910	8.54	8.19	12.02	11.63	8.81	8.45	57.64	
	1911	7.57	9.92	12.38	9.71	10.89	8.77	59.24	

SUMMARY.

The term "water requirement" is used in this paper to indicate the ratio of the weight of water absorbed by a plant during its growth to the weight of dry matter produced. The investigation had for its object the determination of the differences in water requirement exhibited by the more important crop plants and some of their varieties with a view to determining those which are most efficient in the use of water under the semiarid conditions existing in the Great Plains.

The plants were grown in large pots having a capacity of about 115 kilos of soil. The pots were provided with tight covers, with openings for the plants, the space between the cover and the stem of the plant being sealed with wax. The loss of water was thus limited to that occurring from the transpiration of the plants. Water was added, as required, from graduated flasks to a 5-inch flowerpot set in the soil immediately below the cover. Adequate aeration was secured through the changes in the air volume of the soil accompanying the changes in soil-moisture content. The plants were grown in an inclosure covered with a screen of one-fourth-inch mesh as a protection against possible hailstorms. The results of the different water-requirement measurements made at Akron, in northeastern Colorado, in 1911 are shown in Table XXI.

TABLE XXI.—Summary of water-requirement measurements of varieties and crops at Akron, Colo., in 1911.

BASED ON DRY MATTER PRODUCED.

Crop.	Variety.	Water requirement.		
		Of variety.	Of crop.	Relative, compared with wheat.
Alfalfa.....	Grinn.....	1,068±16	1,068	211
Pea, field.....	Canada.....	800±17	800	158
Artemisia frigida.....	765±24	765	151
Rye.....	Spring.....	724±7	724	143
Sweet clover.....	709±9	709	140
Oats.....	(Burt.....	699±7	614	122
	Swedish Select.....	615±7		
	Sixty-Day.....	605±5		
	Canadian.....	598±14		
Buckwheat.....	578±13	578	114
	.....	544±9	
Barley.....	(Beardless.....	543±2	539	106
	Beldi.....	542±3		
	White Hull-less.....	527±8		
	Hannchen.....	534±14		
Wheat.....	Emmer.....	531±5	507	100
	Marvel Bluestem.....	506±3		
	Spring Ghirka.....	496±4		
	Gaigalce.....	498±8		
	Kubanka.....	448±11		
Potato.....	Irish Cobbler.....	441±13	448	88
Rape.....	377±8	441	87
Sugar beet.....	Kleinwanzleben.....	377±8	377	74
Corn.....	(Iowa Silvermine.....	368±10	368	73
	Northwestern Dent.....	319±5		
	Esperanza.....	356±4		
Weed.....	(Amaranthus retroflexus.....	336±5	322	63
	Salicaria perfoliata.....	275±7		
	Amaranthus gracilis.....	333±3		
Sorghum.....	(Dwarf milo.....	321±2	306	60
	White durra.....	301±3		
	Brown kaoliang.....	298±4		
	Red Amber.....	278±5		
	Blackhull kafir.....	287±2		
Millet.....	(Kursk.....	263±15	275	54
	German.....	263±15		

BASED ON GRAIN PRODUCED.

Pea, field.....	Canada.....	2,218±100	2,218	163
Rye.....	Spring.....	2,215±37	2,215	163
Oats.....	(Canadian.....	2,204±140	1,680	124
	Swedish Select.....	1,632±35		
	Burt.....	1,500±57		
	Sixty-Day.....	1,383±30		
Wheat.....	(Marvel Bluestem.....	1,788±60	1,357	100
	Spring Ghirka.....	1,832±43		
	Gaigalce.....	1,245±13		
	Kubanka.....	1,191±14		
	Emmer.....	1,180±42		
Barley.....	(White Hull-less.....	1,475±40	1,244	92
	Beardless.....	1,210±38		
	Beldi.....	1,155±18		
	Hannchen.....	1,134±27		
Buckwheat.....	1,037±33	1,037	76
Millet.....	Kursk.....	923±40		
Sorghum.....	(Dwarf milo.....	1,123±57	790	58
	White durra.....	806±12		
	Blackhull kafir.....	805±26		
	Brown kaoliang.....	726±12		

The standard field crops differ greatly as regards their efficiency in the use of water. Alfalfa, for example, uses four times as much water as millet and the more efficient sorghums in the production of a pound of dry matter. Corn ranks next to sorghum and millet in efficiency in the use of water. The water requirement of the small-grain crops is approximately twice that of millet, but only one-half that of alfalfa. On the basis of grain production alone, the water requirement of millet and the grain sorghums is approximately one-half that of oats and two-thirds that of wheat and barley.

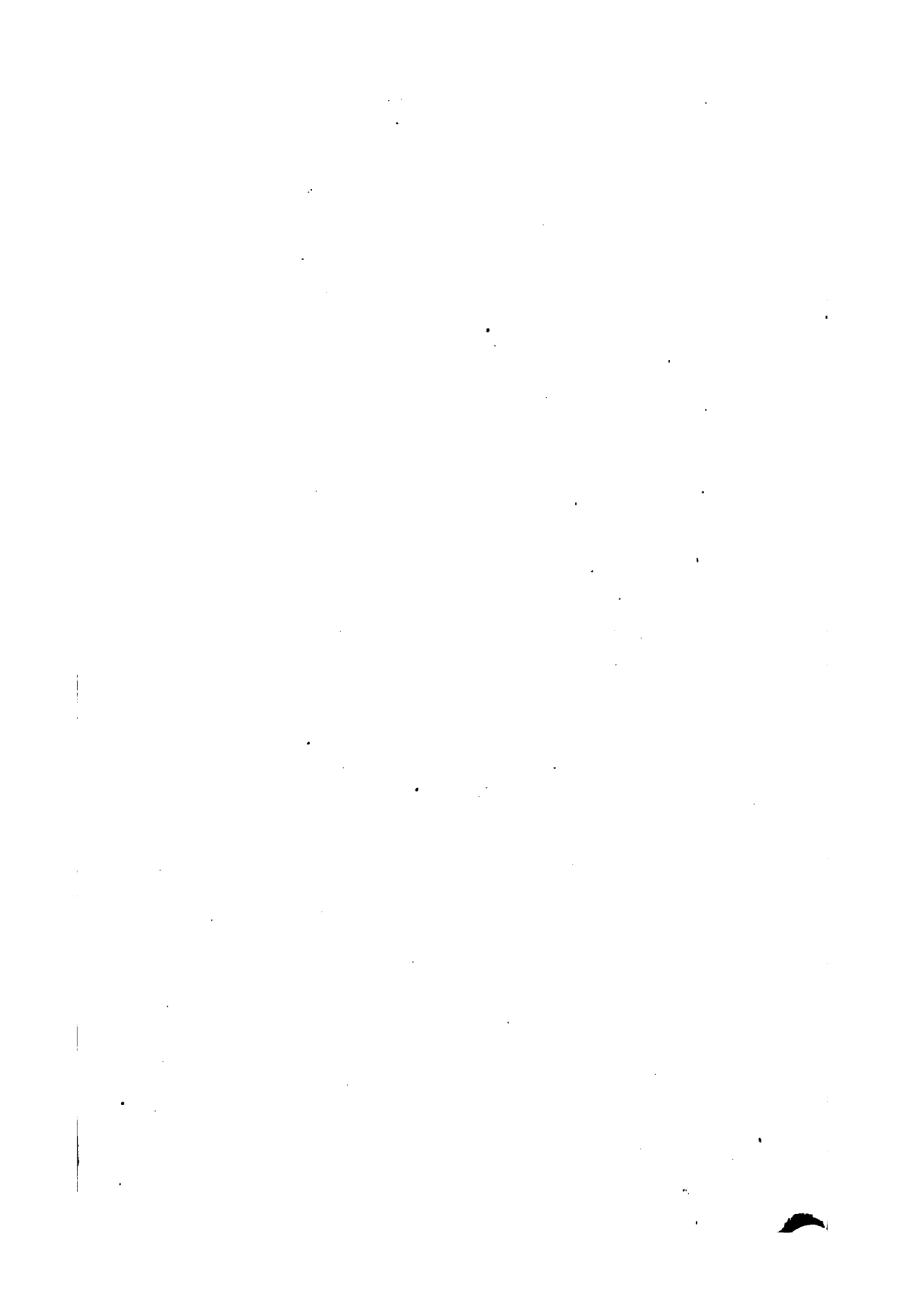
Varieties of the same crop show measurable differences in their water requirement. This suggests the possibility of developing strains which are much more efficient in the use of water than those now grown in dry-land regions.

Determinations were also made during 1910 and 1911 of the water requirement of wheat grown under field conditions. The moisture content of the soil at the beginning and at the end of the experiments was determined through extensive sampling, and the rainfall absorbed by the soil during the period of growth was also computed from daily moisture determinations. The water requirement of Kubanka wheat determined in this way for 1910 and 1911 was found to be 700 and 862, respectively. The water requirement of Kubanka wheat in the pot experiments of 1911 was only 468. Both seasons were deficient in rainfall during the growing period, none of the rains penetrating below the first foot. The rains also occurred at a time when the crop was drawing its moisture supply mainly from stored moisture in the subsoil. If the water supply through rains during the growing season is ignored, the water requirement based upon the amount of stored water removed becomes 486 and 466 for the two years, respectively, which agrees well with the pot determinations. These determinations therefore suggest that wheat is able to make little direct use of light rains coming at a time when the crop is drawing its principal water supply from lower depths.

Measurements of the water requirement of wheat and sorghum at Akron, Colo., and Amarillo and Dalhart, Tex., afford some indication of the influence of climatic conditions on the water requirement. The evaporation from a free water surface in northern Texas during the growth period of wheat and sorghum averaged about 18 per cent above that at Akron, Colo. The water requirement of sorghum was practically the same in the two regions, while the water requirement of wheat averaged 36 per cent higher in northern Texas. This indicates that sorghum is relatively better adapted to northern Texas and that wheat is relatively better adapted to Colorado.

LITERATURE CITED.

	Cited in this bulletin on page—
BRIGGS, L. J., and SHANTZ, H. L.	
1912. The wilting coefficient for different plants and its indirect determination. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 230, 77 p., 2 pl., 9 fig.....	11, 40
1913. The water requirement of plants. II.—A review of the literature. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 285	8
BROWN, M. A.	
1910. The influence of air currents on transpiration. Proceedings, Iowa Academy of Science, v. 17, p. 13-15.....	13
KIESSELBACH, T. A., and MONTGOMERY, E. G.	
1911. The relation of climatic factors to the water used by the corn plant. Nebraska Agricultural Experiment Station, 24th Annual Report, [1910], p. 91-107, 2 fig.....	9
LAWES, J. B.	
1850. Experimental investigation into the amount of water given off by plants during their growth; especially in relation to the fixation and source of their various constituents. Journal, Horticultural Society, London, v. 5, p. 38-63, illus.....	9
LEATHER, J. W.	
1910. Water requirements of crops in India. Memoirs, Department of Agriculture, India, chemical series, v. 1, no. 8, p. 133-184, pl. 3-19 ..	8, 9
SEELHORST, CONRAD VON.	
1906. Über den Wasserverbrauch von Roggen, Gerste, Weizen und Kartoffeln. I. Mitteilung. Journal für Landwirtschaft, Bd. 54, Heft 4, p. 316-342, pl. 18.....	24
1908. Über den Wasserverbrauch von Lupinen im Herbst 1906 und von Kartoffeln, Sommergerste und Roggen im Sommer 1907 auf einem Sandboden. Journal für Landwirtschaft, Bd. 56, Heft 2, p. 199-207..	24
1908a. Über den Wasserverbrauch von Ruben, Roggen, und Gerste auf einem Lehm Boden im Jahre 1907. Journal für Landwirtschaft, Bd. 56, Heft 2, p. 195-198, pl. 12.....	24
SHANTZ, H. L.	
1911. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 201, p. 30-33.....	17



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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 285

WILLIAM A. TAYLOR, *Chief of Bureau.*

261

THE WATER REQUIREMENT OF PLANTS.

II.—A REVIEW OF THE LITERATURE.

BY

LYMAN J. BRIGGS,

Biophysicist in Charge of Biophysical Investigations,

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., June 16, 1913.

SIR: I have the honor to transmit herewith a paper entitled "The Water Requirement of Plants. II.—A Review of the Literature," by Dr. Lyman J. Briggs, Biophysicist in Charge of Biophysical Investigations, and Dr. H. L. Shantz, Plant Physiologist, Alkali and Drought Resistant Plant Investigations. This paper was prepared in connection with their investigations of the water requirement of crop plants in the Great Plains and consists of a review of the various measurements which have been made dealing with the water requirement of crops. It is hoped that this paper may prove of value, not only as a presentation of the present state of our knowledge regarding the amount of water required by crops in the production of a unit weight of dry matter, but in indicating as well the lines along which future investigations in this subject can be most profitably carried on.

I have the honor to recommend the publication of this paper as Bulletin No. 285 of the Bureau series.

Respectfully,

WM. A. TAYLOR,
Chief of Bureau.

Hon. D. F. HOUSTON,
Secretary of Agriculture.

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THE WATER REQUIREMENT OF PLANTS.¹

II.—A REVIEW OF THE LITERATURE.

INTRODUCTION.

The review of the literature relating to the water requirement of plants here presented was begun in connection with the writers' investigations on this subject in the Great Plains. The literature proved to be much more extensive than was anticipated, and it has consequently seemed desirable to present independently a summary of the investigations bearing on this subject, particularly since some of the papers are not readily accessible and since a review of the whole subject has apparently not been undertaken heretofore. In reviewing the papers it has appeared desirable to group them with reference to the various factors which affect the water requirement. When more than one phase of the subject is dealt with in the same paper, the special material relating to each phase of the work has been considered in its appropriate place. In summarizing the papers the endeavor has been to give in tabular form the essential data of each investigation. This will enable the reader to draw his own conclusions from the experimental results independently of any interpretation which the writers may have given.

Among the different subjects which have been investigated in relation to their effect upon the water requirement may be mentioned soil-moisture content, type of soil, cultivation, amount of soil used, fertilizers, temperature, light, humidity, carbon-dioxid content of the air, relative leaf area, defoliation, and duration and period of growth, as well as the water requirement of different kinds of plants when grown under comparable conditions. The division of the subject into these groups has been largely determined by the character of the investigations which have so far been made, and is not presented as an ideal division of the water-requirement problem. The papers which deal with any of the above phases of the water-requirement problem, so far as the writers have been able to consult them, are discussed in the following pages. The full title and reference are given under "Literature cited" at the end of the bulletin. The year of publication in parentheses in the text following the author's

¹ The preparation of this bulletin was carried on in cooperation at every stage between the Office of Alkali and Drought Resistant Plant Investigations and the Office of Biophysical Investigations. The authors' names have been placed alphabetically on the title-page.

name serves to indicate a citation and to identify the paper to which reference is made.

In the general subject of transpiration an immense amount of work has been done, and it is possible in this review to consider only that phase of the subject which related directly to the water requirement. The term "water requirement" is here used to indicate the ratio of the weight of water absorbed by a plant during its growth to the dry matter produced. In most of the investigations described the plants were grown in open pots, and in some cases no correction for the water evaporated directly from the soil was attempted. In such instances we have designated the ratio of the water lost to the dry matter produced as the "water requirement including evaporation."

Much of the work on the effect of the soil or of the nutrient solution on plant growth and transpiration has been done with seedlings. In the measurement of the water requirement, however, the exact determination of the amount of growth is as important a factor as the measurement of the amount of water transpired. When the period of growth is short and the plants are harvested during the seedling stage it is difficult to determine the amount of dry matter produced. If the total dry weight of the plant at the end of the experiment is taken to represent the increase in dry matter, the water requirement will be too low, owing to the error of including much of the original dry matter contained in the seed. If a correction is made for the initial weight of the seed, the final weight may show a loss rather than a gain in dry matter (Le Clerc and Breazeale, 1911, p. 10), and even if a gain in weight is recorded it is impossible to determine how much weight was lost during the early stages of germination. If only the aerial portions of the plants are weighed, the recorded increase is largely due to translocation of material and may bear no direct relation to actual increase of dry matter. It is therefore necessary to lengthen the growth period of the plant until a sufficient amount of dry matter has been produced to make the error due to the initial weight of the seed so small as to be inconsequential if water-requirement measurements or transpiration measurements based on the increase in weight of the plant are to be of value. For the above reasons it was decided, after summarizing the data, to omit from the following discussion, except in special cases, water-requirement measurements based on the weight of seedlings.¹

Investigations like that of Höhnelt (1881), in which the water requirement of forest trees was based on the weight of the leaves

¹ The following publications (arranged chronologically) contain water-requirement measurements based on the weight of seedlings:

SOBAUER, PAUL.

1880. Studien über Verdunstung. Forschungen auf dem Gebiete der Agrikultur-Physik, Bd. 3, pp. 351-490.

1883. Nachtrag zu den Studien über Verdunstung. Forschungen auf dem Gebiete der Agrikultur-Physik, Bd. 6, pp. 79-96.

alone, instead of on the total weight of dry matter produced, have also been omitted.

The earliest water-requirement measurements appear to have been made by Woodward (1699). Lawes (1850) was, however, the first to extend his experiments so as to include the entire growth period of annual crop plants. References to some of the earlier papers dealing with this subject are given by Burgerstein (1904, pp. 154-158) in his work on transpiration. The methods employed in some of the more recent investigations of the water requirement of plants have been summarized by Montgomery (1912).

EFFECT OF SOIL FACTORS ON THE WATER REQUIREMENT.

EFFECT OF SOIL-MOISTURE CONTENT ON THE WATER REQUIREMENT.

IL'ENKOV'S EXPERIMENTS.

The effect of soil-moisture content on the water requirement was first investigated by Il'enkov (1865, p. 162). Buckwheat (*Polygonum fagopyrum*) was planted in five flowerpots containing garden soil, and seven plants were grown in each pot. The pots were exposed in the windows of a room which received the sun at midday. The experiment

PAGNOUL, A.

1898. Essais relatifs à la transpiration des plantes. République Française, Département du Pas-de-Calais, Station Agronomique, Bulletin, pp. 10-15.

LIVINGSTON, B. E.

1905. Relation of transpiration to growth in wheat. Botanical Gazette, v. 40, no. 3, pp. 178-195. Reprinted as Contributions from the Hull Botanical Laboratory, 67.

BRITTON, J. C., AND REID, F. R.

1905. Studies on the properties of an unproductive soil. U. S. Department of Agriculture, Bureau of Soils, Bulletin 26, 39 pp.

JENSEN, C. A., BREAZEALE, J. F., PEMBER, F. R., AND SKINNER, J. J.

1907. Further studies on the properties of unproductive soils. U. S. Department of Agriculture, Bureau of Soils, Bulletin 26, 71 pp.

HARTWELL, B. L., AND PEMBER, F. R.

1908. Relation between the effects of liming and of nutrient solutions containing different amounts of acid upon the growth of certain cereals. Rhode Island Agricultural Experiment Station, 20th Annual Report, 1906-7, pp. 358-380.

WHEELER, H. J., AND PEMBER, F. R.

1908. Effect of the addition of sodium to deficient amounts of potassium upon the growth of plants in both water and sand cultures. Rhode Island Agricultural Experiment Station, 20th Annual Report, 1906-7, pp. 299-357, 1 pl.

KRAUSS, F. G.

1908. Rice investigations. Report of first year's experiments. Hawaii Agricultural Experiment Station, Annual Report, 1907, pp. 67-90, pls. 5-9.

GARDNER, F. D.

1906. Fertility of soils as affected by manures. U. S. Department of Agriculture, Bureau of Soils, Bulletin 48, 59 p.

REED, H. S.

1910. Effect of certain chemical agents upon the transpiration and growth of wheat seedlings. Botanical Gazette, v. 49, no. 2, pp. 81-109, 9 figs.

BOUYOUKOS, G. J.

1912. Transpiration of wheat seedlings as affected by soils, by solutions of different densities, and by various chemical compounds. Proceedings, American Society of Agronomy, v. 3, 1911, pp. 130-191, 16 figs. See also Transpiration of wheat seedlings as affected by different densities of a complete nutrient solution in water, sand, and soil cultures. Beihette, Botanisches Centralblatt, Abt. 1, Bd. 29, Heft 1, pp. 1-20, 8 figs., 1912.

DACHNOWSKI, ALFRED.

1912. The nature of the absorption and tolerance of plants in bogs. Botanical Gazette, vol. 54, no. 6, pp. 503-514.

was continued for 57 days. The results of the experiments are shown in Table I. The water-requirement ratio is based on the water added to each pot instead of on the water actually used.

TABLE I.—*Effect of different amounts of water on the water requirement of buckwheat, according to Il'enkov (1865, p. 162).*

Pot No.	Water added.		Dry weight (grams).	Water requirement.
	Relative.	Liters.		
1.....	1	25.0	6.20	4,080
2.....	$\frac{1}{2}$	12.5	13.94	900
3.....	$\frac{1}{3}$	6.25	6.28	995
4.....	$\frac{1}{4}$	3.12	1.93	1,616
5.....	$\frac{1}{5}$	1.56	.39	4,000

Water was not added daily, but pot No. 1 was kept nearly saturated. The table shows that the water requirement was very high, owing probably to the fact that the experiment was conducted in porous pots. Since no account is taken of evaporation or of the initial and final moisture content of the soil, the results are far from conclusive.



FIG. 1.—Glass jar employed by Fittbogen (1873) in measuring the water requirement of plants.

FITTBOKEN'S EXPERIMENTS.

Fittbogen (1873) conducted a series of careful experiments on the influence of soil-moisture content on the water requirement of the oat plant. He used glass jars of the form shown in figure 1. Each jar contained 3 to 4 kilograms of soil, which rested on a 4-centimeter layer of gravel. The jar was closed with a zinc cover (a) having two tubulures. The center tubulure carried a cork (b) bored with a 6-millimeter hole, through which the stems of the three oat plants passed. The other tubulure was kept closed with a cork stopper (c) except when water was being applied. Fittbogen thus had a nearly closed system, and the evaporation loss must have been small.

Five series of experiments were made with different soil-moisture contents, as shown in Table II.

TABLE II.—*Effect of different soil-moisture contents on the water requirement of oats, according to Fittbogen (1873, p. 359).*

Production.	Water content, in terms of moisture-holding capacity.				
	10 to 20 per cent.	20 to 30 per cent.	30 to 40 per cent.	40 to 60 per cent.	60 to 80 per cent.
Dry matter.. { Mean weight, grams ¹	1.6	7.8	12.8	12.2	13.7
{ Water requirement.....	406±14	414±10	444±7	457±9	534±14
Grain..... { Mean weight, grams.....	0.6	4.1	6.1	5.3	6.0
{ Water requirement ²	1,022±96	790±12	934±26	1,050±16	1,213±59

¹ 4 pots used in each determination; 3 plants per pot.

² Computed from Fittbogen's data.

Table II shows that the production of dry matter was very much reduced by the low soil-moisture content. The water requirement also decreased gradually but consistently with the decrease in the water content of the soil, except for grain production in the case of the lowest moisture content, which was apparently too low to support good growth, as is shown by the small amount of dry matter produced.

HELLRIEGEL'S EXPERIMENTS.

Hellriegel (1883) gives the results of three years' observations on the effect of soil-moisture content on the water requirement of barley. The pots used in his investigation contained about 4 kilograms of soil. Surface evaporation in the experiments conducted in 1871 was reduced by the use of covers cemented to the pots. The size of the opening for the plants is not stated. In his earlier experiments a correction for the direct evaporation was made, based upon the loss from the check pots. Hellriegel's results are given in Table III.

TABLE III.—*Effect of different soil-moisture contents on the water requirement of barley, according to Hellriegel (1883).*

Year and production. ¹	Water content, in terms of moisture-holding capacity.						
	5 per cent.	10 per cent.	20 per cent.	30 per cent.	40 per cent.	60 per cent.	80 per cent.
1869.							
Dry matter.....{Mean weight.....grams.....			17.9		23.9	25.4	24.5
Water requirement.....			254±10		258±2	281±13	298±4
1870.							
Dry matter.....{Weight.....grams.....	0.1	3	14.6	19.8	21.8	22.8	19.7
Water requirement.....	940	180	168	223	216	240	277

Year and production. ¹	Water content, in terms of moisture-holding capacity.			
	5 to 15 per cent.	15 to 25 per cent.	20 to 60 per cent.	40 to 80 per cent.
1871.				
Dry matter.....{Weight.....grams.....		8.1	31.3	49.0
Water requirement.....		192	239	261

¹ Three pots used in each determination in 1869; single pots in 1870 and 1871.

These results indicate also that the water requirement of plants decreases within limits as the soil-moisture content is lowered, but is also accompanied by a decrease in dry matter. In the duplicated series of experiments the reduction of the moisture content from 80 per cent saturation to 20 per cent reduced the water requirement of barley about 15 per cent.

MAERCKER'S EXPERIMENTS.

Maercker (1896) investigated the influence of soil-moisture content on the water requirement of white mustard in connection with

certain fertilizer experiments. A summary of his results is given under "Effect of fertilizers on the water requirement" (Table XXVII, p. 36). He found that white mustard grown in soil 20 per cent saturated had a water requirement nearly 30 per cent less than when grown in soil 60 per cent saturated. His pots were not protected from surface evaporation.

SCHROEDER'S EXPERIMENTS.

Schroeder (1896) investigated the water requirement of barley when grown in sand moistened with nutrient solutions of different concentration. The effect of different amounts of solution was also investigated, three series of pots being maintained, respectively, at 80, 40, and 20 per cent of the moisture-holding capacity. His results are given in Table IV. The data for 1894 show a consistent reduction in the water requirement accompanying a reduction of the moisture content of the soil. Schroeder placed less confidence in the results for 1893 on account of the imperfect prevention of direct evaporation by the layer of cotton employed for that purpose.

TABLE IV.—*Effect of different amounts of nutrient on the water requirement of barley in Russia, according to Schroeder (1896, pp. 194-211).*

Year.	Soil moisture, in terms of water-holding capacity.	Concentration of nutrient solution.	Dry matter.	Water requirement.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Grams.</i>	
		0.6	33.93	568
		.4	28.22	547
	80	.3	20.81	586
		.2	15.42	576
		.1	6.40	513
		.6	20.07	505
1894 ¹	40	.4	16.84	470
		.3	9.50	536
		.2	7.72	424
		1.2	15.35	338
		.8	10.66	399
	20	.6	6.36	400
		.4	5.87	429
		.2	3.53	360
	70 to 100	1.7	8.15	579
	40 to 70	2.4	6.25	516
	5 to 40	4.3	3.50	472
1893 ²	40 to 70	1.2	4.23	414
	40 to 70	3.7	7.67	541
	5 to 40	6.4	4.54	467
	70 to 100	.85	6.28	329

¹ Experiments were conducted in glass pots filled with 5 kilograms of sterile sand. The soil surface was covered by oilcloth and a layer of cotton. The pots were taken into a shelter during the night and in bad weather. Growth continued from 70 to 83 days. Only one pot was used in each culture. The initial weight of the seed was deducted in estimating the water requirement. The nutrient solution was the same as that used by Hellriegel (p. 13).

² As in 1894, but the pots contained sand plus 150 grams of peat. The surface of the pot was covered with only a layer of cotton. Growth continued from 71 to 113 days.

VON SEELHORST'S EXPERIMENTS.

Von Seelhorst (1899) has determined the effect of different percentages of soil moisture on the water requirement of oat plants which were harvested just before the milk stage. Pots containing about 10

kilograms of soil were used. His results, which are expressed in terms of air-dry weight and include also the effects of fertilizers on the water requirement, are given in Table XXVIII (p. 38). The range in soil moisture in these experiments was small, and the effect upon the water requirement is not marked.

WILMS'S EXPERIMENTS.

Wilms (1899) investigated the effect of different soil-moisture contents on the water requirement of potato tubers (green weight) and obtained results which are in accordance with those already noted. The pots contained about 17 kilograms of soil and were not covered, but the water was applied through a Liebecher air-circulation tube, so that the surface soil always remained dry. The results of the investigation, which includes also the effect of various fertilizers on the water requirement, are given in Table XXIX (p. 39). The mean values obtained by Wilms are as follows:

Moisture-holding capacity.....	per cent..	33, 58, 80
Water requirement.....	green weight..	39, 50, 62

DASZEWSKI'S EXPERIMENTS.

Daszewski (1900) determined the dry weight of the tubers from a few of Wilms's pots. The combined data (Table V) show that the water requirement was greatly increased in the soil with the higher water content.

TABLE V.—*Effect of different amounts of soil moisture on the water requirement of potato tubers.*¹

Fertilizer used.	Water content, in terms of moisture-holding capacity.				Mean water requirement.
	33 per cent.		58 per cent.		
	Dry tubers.	Water requirement.	Dry tubers.	Water requirement.	
	<i>Grams.</i>		<i>Grams.</i>		
None.....	50.7	98	72.5	156	127
Na ₂ SO ₄	58.8	84	68.8	161	122
K ₂ SO ₄	61.2	85	98.1	131	108
KNO ₃	90.9	87	147.0	136	111
MgSO ₄	55.7	92	78.7	150	121
Mean.....		89		147	

¹ Combined from Wilms (1899, p. 298-299) and Daszewski (1900, p. 240); the data as given are the mean of two pots.

FORTIER'S EXPERIMENTS.

Fortier (1903), using pots 18 inches in diameter, 30 inches deep, and containing 19 plants of Swedish Select oats, obtained the results given in Table VI. The first column of the table gives the total amount of water added to each pot expressed in terms of inches of rainfall. The water lost apparently includes the evaporation from the soil, though

this is not definitely stated. The pots were apparently weighed only at the beginning and at the end of the experiment. Although the dry matter increased progressively with the increased supply of water, the water requirement reached its minimum with the use of from 20 to 22 inches of water, increasing with either a greater or a smaller supply of water.

TABLE VI.—*Effect of the amount of water added on the water requirement of oats, at Bozeman, Mont., according to Fortier (1903, p. 107).*

Water added.	Dry matter.	Water requirement.
<i>Inches.</i>	<i>Grams.</i>	
2.....	55	501
6.....	76	574
14.....	145	525
20.....	236	434
22.....	252	433
22.....	264	413
32.....	312	528
38.....	316	552

VON SEELHORST AND BÜNGER'S EXPERIMENTS.

Von Seelhorst and Bünger (1907) conducted a fertilizer test with high and low soil-moisture content, using open pots containing 12 kilograms of soil. This experiment was made on spring wheat. The results (Table XXXII, p. 44) indicate a higher water requirement in soil of high moisture content.

OHLMER'S EXPERIMENTS.

Ohlmer (1908) also employed two different soil-moisture contents in connection with a fertilizer experiment with wheat at Gottingen (Table XXXIII, p. 45). The comparison was made with 11 different combinations of fertilizers, and in every instance the lower soil-moisture content gave the lower water requirement. The average of all the tests shows that a decrease in the soil-moisture content from 70 per cent of the water-holding capacity to 45 per cent decreases the mean water requirement by 12 per cent. Open pots were used.

WIMMER'S EXPERIMENTS.

Wimmer (1908) published the results of an extensive series of experiments to determine the effect of fertilizer on the water requirement of carrots and ray-grass. Open pots were used, the method being the same as that employed by Wilfarth and Wimmer (1902).

The results (Table VII) show no significant differences that can be attributed to the different soil-moisture contents employed. In several of the series differences are found which might be considered significant if they were at all consistent. As a whole, the data indi-

cate that within the limits of this experiment different soil-moisture contents do not affect the water requirement of crops. The difference in soil-moisture content was very small, usually not more than 3 per cent. In view of this slight difference, combined with the uncertainty introduced by using open pots, it is not surprising that Wimmer's results do not show the influence of moisture content on the water requirement that other investigators have observed.

TABLE VII.—*Effect of different soil-moisture contents on the water requirement of carrots and ray-grass, according to Wimmer.*¹

CARROTS.²

Year, period, and plat.	Previous fertilizer.	Soil per pot.	Fertilizer per pot.	Soil moisture.	Mean dry matter.	Water requirement.
		<i>Grams.</i>	<i>Grams.</i>	<i>Per ct.</i>	<i>Grams.</i>	
May 3 to Oct. 30, 1903: Waldau 33, 34, 35.....	No potash since 1902.....	7,556	0.280N	14	21.4	430±26
			.280	17	31.0	419±19
			.280	20	32.1	466±31
			.700	14	22.2	302±26
			.70L	17	31.0	412±14
			.700	20	43.8	386±16
			.280	14	19.6	458±17
			.280	17	31.9	352±10
F 1, 3, 5, 7.....	.....do.....	7,556	.280	20	32.1	442±22
			.700	14	17.3	470±46
			.700	17	28.5	393±14
			.700	20	44.2	309±15

RAY-GRASS.³

May 1 to Nov. 1, 1903: Waldau 33, 34, 35.....	{No potash since 1902; 0.284 gram P ₂ O ₅ per pot.	7,556	.280	12	34.1	230±20
			.280	15	35.4	372±22
			.280	18	44.0	329±38
			.700	12	43.8	264±10
			.700	15	52.2	232±10
			.700	18	53.7	322±10
			.280	12	33.9	323±12
			.280	15	44.9	302±12
F 1, 3, 5, 7.....	.....do.....	7,556	.280	18	48.3	319±19
			.700	12	39.6	285±8
			.700	15	51.7	259±4
			.700	18	57.7	298±7
June 1 to Oct. 18, 1904: B 1 ⁴	{No potash, 1891 to 1904; stable manure, 1891 to 1896; green manure, 1901.	6,766		15	66.9	302±1
				18	76.7	307±21
			.155K ₂ O	15	63.6	295±34
			.155	18	78.5	343±34
			.776	15	69.9	266±3
			.776	18	80.3	316±4
				15	71.5	302±8
				18	84.5	288±5
			.155	15	66.3	322±22
			.155	18	85.9	275±11
			.776	15	68.7	324±3
			.776	18	72.9	312±27
B 3 ⁴	None, 1891 to 1904.....	6,903		15	57.0	265±14
				18	69.4	367±1
			.155	15	60.8	286±55
			.155	18	66.6	376±5
B 5 ⁴	Same as B 1.....	6,791	.776	15	67.8	290±17
			.776	18	78.4	283±11
				12	39.7	346±8
				15	44.7	346±13
E 3.....	No potash since 1901.....	6,397		18	49.9	347±9
				12	32.8	343±16
Waldau 87, 88, 89.....	No potash since 1900.....	7,359		15	45.7	321±11
				18	55.3	398±42

¹ Computed from Wimmer's data (1908, pp. 43-89); mean of three determinations except as noted.

² The same data in Table XLIII (p. 55), under "Effect of nitrogen," are recorded under 12, 15, and 18 per cent of water, respectively. The original does not show which record is correct.

³ Each pot received 0.284 gram of P₂O₅ in 1903 and 1.120 grams N and 0.284 gram P₂O₅ in 1904.

⁴ The mean of two determinations.

TABLE VII.—*Effect of different soil-moisture contents on the water requirement of carrots and ray-grass, according to Wimmer—Continued.*

RAY-GRASS—Continued.

Year, period, and plat.	Previous fertilizer.	Soil per pot.	Fertilizer per pot.	Soil moisture.	Mean dry matter.	Water requirement.
		Grams.	Grams.	Per ct.	Grams.	
Apr. 17 to Sept. 26, 1905: B 3 ¹	None, 1901 to 1905.....	7,919	15	92.4	313±4	
			18	95.6	333±17	
			0.155	93.8	306±21	
			.155	98.7	336±1	
			.776	92.5	310±7	
			.776	100.4	350±16	
			15	90.0	305±13	
			18	113.4	290±4	
			.155	88.4	319±32	
			.155	104.3	303±7	
F 3 ¹	do.....	7,768	.776	90.0	312±17	
			.776	102.1	311±7	
			15	80.2	341±32	
			18	90.6	345±12	
			.155	84.7	311±11	
H 3 ¹	No potash, 1902 to 1905.....	7,344	.155	93.5	306±7	
			.776	96.2	262±9	
			.776	95.9	331±3	
			280N	41.5	406±5	
			280	46.2	440±4	
F 3 ¹	No potash since 1901.....	7,768	280	50.9	439±27	
			280	39.9	352±19	
			280	48.6	397±18	
Waldau ¹ 87, 88, 89.....	No potash since 1903.....	8,042	280	46.9	458±11	
			12	43.0	373±35	
			15	46.0	454±19	
F 6 ¹	Kainit since 1902.....	7,808	18	46.3	523±6	
			9	41.5	423±6	
			14	44.0	441±5	
Juetrichau sand ¹		8,000	14	45.4	461±4	
			7	26.0	521±14	
			9	36.0	422±23	
Buhlendorf sand ¹		8,000	11	33.8	460±27	

¹ The mean of two determinations.

PREUL'S EXPERIMENTS.

Preul (1908) investigated the effect of different soil-moisture contents for varying periods upon the water requirement of wheat. The experiments were conducted with two different soils and the soil moisture was maintained at 45 and at 80 per cent of the moisture-holding capacity. Open pots were used in these experiments. A correction based upon the evaporation from check pots was made for evaporation, although it was not clear that a check was provided for each series of observations. The results (Table VIII) show a gradual decrease in the water requirement with the increase of the period during which the lower soil-moisture content was maintained. The lowest water requirement was obtained in the soil kept continuously at the lower water content.

TABLE VIII.—*Effect of different soil-moisture contents on the water requirement of squarehead summer wheat,¹ according to Preul (1908, pp. 12-13).*

Soil moisture, in terms of moisture-holding capacity during period.		Water requirement in—	
45 per cent.	80 per cent.	Rich soil.	Poor soil.
Mar. 12 ² to July 31.....		158±1	224±4
Mar. 12 to July 1.....	July 1 to July 31.....	147±6	220±7
Mar. 12 to June 15.....	June 15 to July 31.....	228±7	274±3
Mar. 12 to June 1.....	June 1 to July 31.....	235±2	281±4
Mar. 12 to May 15.....	May 15 to July 31.....	248±2	268±4
Mar. 12 to May 1.....	May 1 to July 31.....	251±1	261±3
	Mar. 12 ² to July 31.....	248±5	259±1
July 1 to July 31.....	Mar. 12 to July 1.....	209±1	263±4
June 15 to July 31.....	Mar. 12 to June 15.....	207±4	259±2
June 1 to July 31.....	Mar. 12 to June 1.....	207±3	222±5
May 15 to July 31.....	Mar. 12 to May 15.....	194±1	256±4
May 1 to July 31.....	Mar. 12 to May 1.....	187±8	246±3
Mean.....		210	253

¹ Zinc pots were used in these experiments. They were 33 centimeters in height, 25 centimeters in diameter, and contained 20.5 kilograms of soil. Each series consisted of 3 or 4 pots, 66 pots being used in all. The poor soil consisted of good soil mixed with heath sand. Each pot contained 1.47 grams K_2CO_3 and 1.65 grams $CaH_2(PO_4)_2$. In addition, each pot of good soil received 9.11 grams $NaNO_3$ and each pot of poor soil 3.04 grams of $NaNO_3$. Each pot of good soil contained 18 wheat plants and the pots of poor soil 9 wheat plants each. Several minor errors occurring in the original data have been corrected here.

² The pots of good soil were planted Mar. 12 and those of poor soil Mar. 16.

WIDTSON'S EXPERIMENTS.

Widtsoe (1909) investigated the effect of the soil-moisture content on the water requirement of wheat, sugar beets, corn, and peas (Table IX). Maximum water contents of 10 and 20 per cent of saturation were chosen, and when any plant needed water all pots were brought up to weight. The pots were of galvanized iron, 24 inches in diameter and 30 inches high. A single open pot of each crop was used for each moisture content, the evaporation from a bare control pot being deducted. The results for the same crop fluctuate to such an extent from year to year as to render conclusions uncertain except in the case of corn, where the lower moisture content consistently gave the higher water requirement.

TABLE IX.—*Influence of soil-moisture content on the water requirement of certain crops, according to Widtsoe (1909, p. 39).*

Crop.	Saturation.	Water requirement.				Ratio of water requirement, low to high soil moisture.				
		1902	1903	1904	1905	1902	1903	1904	1905	Average.
Wheat.....	Per cent.									
	10	258	340	755	356	}0.51	0.65	1.13	1.36	0.91±0.16
	20	511	523	664	261					
Sugar beets.....	10	639	227	645	570	}1.52	.33	1.60	1.21	1.17±.20
	20	420	696	403	469					
Corn.....	10	490	280	424	697	}1.21	1.09	1.54	2.28	1.53±.19
	20	406	256	276	306					
Peas.....	10	1,558	269	510	525	}2.05	.34	.30	.....	.90±.46
	20	808	789	1,704	.....				

LEATHER'S EXPERIMENTS.

Leather (1910) has also investigated the influence of the soil-moisture content on the water requirement of wheat and corn at Pusa, India. His determinations are given in detail in Table XXXIX (p. 51), each determination being based upon a single open jar. From these measurements the writers have computed the mean water requirement obtained for each soil-moisture content when different fertilizers were used. These means are to be found in the last columns of the tables referred to and are, of course, comparable only in so far as they apply to jars of the same size and to the same series of fertilizers. A summary of the observations for each soil-moisture content, obtained by averaging the mean values found with pots of different capacity, is also given in Table X. The results are seen to be in agreement within the limits of experimental error. In other words, an increase in the moisture content of Pusa soil from 10 to 20 per cent of the saturation content did not affect the water requirement by an amount exceeding the experimental error.

TABLE X.—*Effect of soil-moisture content on the water requirement of wheat and corn at Pusa, India, according to Leather (1910, p. 133).*

Crop.	Year.	Total pots used with each water content.	Water requirement with—		
			10 per cent water.	15 per cent water.	20 per cent water.
Wheat.....	{ 1906-7 1907-8	8 6	747 562	707 -----	737 748
Corn.....	1907	9	414	404	436

KIESSELBACH'S EXPERIMENTS.

Kiesselbach (1910) has measured the effect of soil-moisture content on the water requirement of corn at Lincoln, Nebr., using covered 4-gallon glazed stone jars, containing 14.5 kilograms of dry loam.

Water was added through a tube to a reservoir formed by inverting a 4-inch flower pot in the bottom of the jar. Surface evaporation was prevented by the use of gravel and paraffined parchment paper. The plants were grown in a cornfield, one plant to a jar. An oilcloth cover was used on each jar to keep out rain, and a temporary canvas cover was put on during rainstorms. The jars were weighed once in 48 hours and sufficient water added each time to restore the original weight. The variation in degree of saturation during this period ranged from 5 to 10 per cent. The plants were harvested shortly after the silking stage. The results are shown in Table XI. The plant grown in soil 20 per cent saturated wilted when the conditions gave rise to high transpiration. This may be associated with the slightly lower water requirement recorded in the case of these plants.

No differences in the water requirement greater than the probable error occur in the case of the plants grown at other degrees of saturation.

TABLE XI.—*Influence of soil-moisture content on the water requirement of corn, according to Kiesselbach (1910, p. 125).*

Saturation.	Average dry weight, without roots.	Water requirement based on dry weight.	
		Excluding roots.	Including roots.
<i>Per cent.</i>	<i>Grams.</i>		
98	91.1	270	242 ± 5
80	93.1	272	239 ± 9
60	100.6	256	227 ± 10
40	92.9	270	233 ± 7
20	83.2	239	201 ± 5

KIESELBACH AND MONTGOMERY'S EXPERIMENTS.

Kiesselbach and Montgomery (1911) extended Kiesselbach's investigation with corn, using large pots in which the plants were brought to maturity. Single plants were grown in galvanized-iron pots 16 inches in diameter and 3 feet deep. The construction of their potometer is shown in figure 2. Water was added through a perforated $\frac{3}{8}$ -inch brass pipe 15 feet long bent in the form of a helical coil. Evaporation from the soil was minimized by a layer of gravel 3 inches deep. Rain was excluded with the aid of a galvanized-iron lid having a 4-inch opening in the center for the plant, the opening being covered with oilcloth closely fastened about the cornstalk. The potometers were located in a cornfield and were apparently sunk in trenches so that the tops of the pots were level with the surface of the surrounding field. The potometers were mounted on small, individual trucks and were run on tracks to a platform scale which was mounted on a cross track.

Five different degrees of soil saturation were maintained, namely, 100, 80, 60, 45, and 35 per cent. Saturation was regarded as the amount of water retained by the soil when drainage had ceased after pouring water on the soil surface. One hundred pounds of water

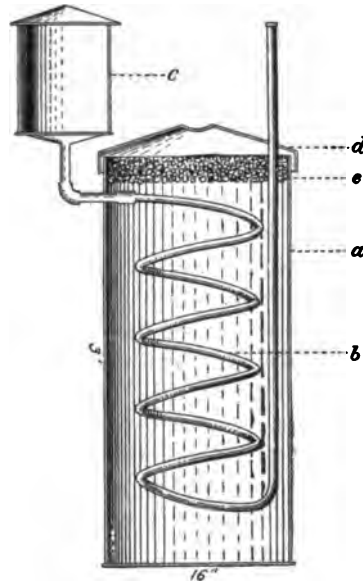


FIG. 2.—Pot employed by Kiesselbach and Montgomery (1911) in measuring the water requirement of corn.

were required to saturate 260 pounds of moisture-free soil in each potometer. The average moisture contents, expressed in terms of the dry weight of the soil, would then be as follows: 38, 31, 23, 17, and 13.4 per cent. The nonavailable moisture was estimated at 12 per cent. This gave a very small margin of available moisture in the driest pots, and these plants often wilted and rolled. The average dry weight (based upon four plants) and the moisture requirement for the different degrees of saturation are given in Table XII:

TABLE XII.—*Effect of soil-moisture content on the water requirement of corn, according to Kiesselbach and Montgomery (1911, p. 91).*

Saturation.	Dry weight.	Water re- quirement.
<i>Per cent.</i>	<i>Grams.</i>	
100	373	290 ± 4
80	484	263 ± 5
60	442	239 ± 10
45	297	280 ± 7
35	112	261 ± 17

Kiesselbach and Montgomery attribute the higher value obtained in "saturated" soil to some physiological disturbance, indicated by the reduced plant growth. The plants grown in soil 45 per cent and 35 per cent saturated were also much smaller than the others. Diminished growth is often accompanied by an increase in the water requirement. This is partly offset in the present case by the fact that the evaporation conditions to which the shorter plants were subjected were less severe. The relative evaporation from jars of water placed at 0, 2, 4, 6, 8, and 10 feet above ground in the cornfield was respectively 1, 1.15, 1.32, 1.53, 1.65, 1.75.

A consideration of the probable errors indicates that an actual reduction of the water requirement accompanies the reduction of the saturation water content from 100 to 80 or 60 per cent. A further apparent reduction also occurs when the saturation water content is reduced to 45 per cent, but as already stated this may be due to the protection given by the taller surrounding plants. The probable error in the series with the lowest water content (35 per cent saturated) is so high as to make conclusions uncertain.

PFIEFFER, BLANCK, AND FLÜGEL'S EXPERIMENTS.

Pfeiffer, Blanck, and Flügel (1912) carried on a series of experiments with oats to determine the effect of different soil-moisture contents on the water requirement. About 18 kilograms of sand were used per pot. The plants were grown in three series, one kept constantly at 10 per cent soil moisture, another at 7 per cent, and a third allowed to fluctuate between 10 per cent and the wilting point (4 per cent). Twenty-four plants of Ligowo oats were used per pot. The pots were kept in the greenhouse during rainy weather and moved

out at other times. The experiments extended from April 29 to July 16 and July 30. The results of these investigations are given in Table XIII. The plants were grown in open pots, without bare check pots, but a correction for loss due to evaporation from the soil surface was made in the following way: The mean value of the water consumption and of dry matter, respectively, for four pots from each moisture-content series, grown without nitrogen, was subtracted from the water consumption and dry matter of each individual fertilized pot of that series. The ratio of the remainders was taken to represent the water requirement of the plants grown in that pot. This correction ranges from nearly one-half of the total water consumption in the case of the low-nitrogen pots to about one-seventh of the water consumption in the high-nitrogen pots.

An analytical examination of this method of correcting for evaporation shows that it can not be justified.

Let t_o = total water transpired and evaporated from pot without nitrogen.

t = total water transpired and evaporated from pot with nitrogen.

e_o = water evaporated from soil of pot without nitrogen.

e = water evaporated from soil of pot with nitrogen.

w_o = dry weight of unfertilized plants.

w = dry weight of fertilized plants.

r_o = water requirement of unfertilized plants.

r = water requirement of fertilized plants.

Then, by definition,

$$\frac{t_o - e_o}{w_o} = r_o \quad (1)$$

and, similarly,

$$\frac{t - e}{w} = r. \quad (2)$$

Subtracting equation 1 from equation 2, we have—

$$t - t_o + e_o - e = rw - r_o w_o. \quad (3)$$

Pfeiffer, Blanck, and Flügel, in calculating the water requirement, took the difference between the water loss from the fertilized and unfertilized pots and divided this by the corresponding difference in dry weight. The quotient was considered to be the water requirement of the plants in the fertilized pot. Expressed as an equation, this becomes—

$$\frac{t - t_o}{w - w_o} = r \quad (4)$$

or,

$$t - t_o = r(w - w_o). \quad (5)$$

Subtracting equation 5 from equation 3, we have—

$$e_o - e = (r - r_o)w_o, \quad (6)$$

which is the assumption that Pfeiffer, Blanck, and Flügel really make in following their method of reducing the results. Writing equation 6 in the form—

$$\frac{e_o - e}{w_o} = r - r_o,$$

it will be seen, first, that their assumption is that the difference in the transpiration ratios of two series is proportional to the difference in

the amount of soil evaporation from the series, factors which obviously have no dependence one upon the other; and, second, that if the soil evaporation from the two series was made equal, the water requirement of the two series would have to be equal, irrespective of the method of treatment! It is evident from this analysis that the method of reduction employed by Pfeiffer, Blanck, and Flügel is not sound, and that consequently no weight can be attached to the data as given. The data without the correction for evaporation are, unfortunately, not given in the original paper.

TABLE XIII.—*Effect of different soil-moisture contents on the water requirement of oats,¹ according to Pfeiffer, Blanck, and Flügel (1912, p. 230).*

Nitrogen applied per pot. ²	Water requirement with—				
	High water content, 10 per cent.	Low water content, 7 per cent.	Varying water content, 4 to 10 per cent.	High water content and shade, 10 per cent.	Mean.
<i>Grams.</i>					
0.355	397 ± 5	348 ± 5	344 ± 1	406 ± 2	374
.710	388 ± 4	341 ± 2	281 ± 4	419 ± 2	357
1.065	372 ± 3	304 ± 7	273 ± 3	392 ± 4	336
1.420	373 ± 6	371 ± 3	292 ± 4	401 ± 4	359
1.775	397 ± 4	388 ± 5	307 ± 4	433 ± 4	381
2.130	414 ± 7	372 ± 4	301 ± 4	383 ± 4	368
Mean	390 ± 2	354 ± 2	300 ± 2	410 ± 2 ³	363

¹ Twenty-four plants of Ligowo oats were grown in each pot. The pots contained 18 kilograms of sand of low moisture-holding capacity. There were four pots for each determination. The dry matter produced is not given.

² Applied as ammonium nitrate.

³ Pfeiffer, Blanck, and Flügel omitted four pots in calculating this mean because the plants were not artificially shaded. These pots apparently formed the series whose mean is 383 ± 4.

CONCLUSIONS.

In general, the results of the experiments herein recorded show an increase in the water requirement when the water content of the soil approaches either extreme. Many of the experiments were conducted in open pots and the evaporation estimated by means of check pots, which is an uncertain procedure. Extreme moisture conditions might, however, affect the water requirement indirectly. With a high water content, the aeration would be reduced and the soil solution would be diluted. In the case of soils kept at a low water content, the small amount of water required from time to time to bring the pot to normal weight is sufficient to moisten only a comparatively small portion of the soil mass. In effect, then, the low soil-moisture plants are growing in a very restricted soil mass as compared with plants grown with an optimum soil-moisture content. This condition might cause an increase in the water requirement of plants grown in a comparatively dry soil due to a deficiency of plant food. In view of these considerations the writers believe that the direct influence of soil-moisture content on the water requirement can not be established without further investigation.

EFFECT OF SOIL TYPE ON THE WATER REQUIREMENT.

MARIÉ-DAVY'S EXPERIMENTS.

Marié-Davy reports experiments (Table XIV) which were designed to show the effect of different soils on the water requirement of wheat for grain production. In the first series (1875), 2-liter glass containers with small necks were employed and direct evaporation practically eliminated. Each soil was given 10 different treatments, but since the different soils received the same series of treatments, a comparison on the basis of the soil is possible. In the later experiments (1876) large, open casks, 1 meter square, were employed. A single cask of soil was used in each treatment, leaf mold being added in varying amounts. The addition of the leaf mold does not appear to have had beneficial effects except in the case of soil from Saint-Ouen. In all other cases it increased the water requirement of wheat for grain production. The total dry matter is not recorded and no adequate description of the soils is given. The differences recorded are probably due partly to soil differences, although the lack of agreement in the two tables indicates rather high experimental errors. It is probable, however, that had the water requirement been computed on the total dry matter the results would have been modified. The addition of leaf mold often increases the straw as compared with the grain yield, and this may account for the high water requirement for grain when leaf mold was employed.

TABLE XIV.—*Effect of different soils on the water requirement of wheat, according to Marié-Davy.*

Soil employed.	Period.	Dry grain.	Water requirement, based on grain.
Montsouris plus fertilizer.....	1874 ¹	3.99	1,126
Saint-Ouen plus fertilizer.....		5.48	1,034
Gravelle plus fertilizer.....		5.65	1,010
Dornecy (brown) plus fertilizer.....		4.13	1,435
Ivry plus fertilizer.....		5.09	1,056
Vincennes plus fertilizer.....		6.06	1,015
Fontenay sand ² plus fertilizer.....		4.20	1,364
Montsouris plus 25 kilograms leaf mold.....	1874. ² Feb. 1 to July 23..	394	964
Saint-Ouen plus 25 kilograms leaf mold.....		300	1,160
Saint-Ouen plus 50 kilograms leaf mold.....		380	913
Gravelle plus 25 kilograms leaf mold.....		303	1,122
Gravelle plus 50 kilograms leaf mold.....		256	1,337
Dornecy (brown) plus 50 kilograms leaf mold.....		328	1,047
Peat.....		324	1,015
Dornecy (red) plus 50 kilograms leaf mold.....		312	1,087
Vincennes plus 25 kilograms leaf mold.....		308	1,163
Vincennes plus 50 kilograms leaf mold.....		313	1,105
Ivry plus 25 kilograms leaf mold.....		236	1,576
Ivry plus 50 kilograms leaf mold.....			

¹ 1875 (pp. 306-310). Ten pots of each soil each of 2 liters capacity and each receiving one of the fertilizers given in table. Evaporation from the soil practically eliminated. In Marié-Davy (1874) many of the data given in this table are presented in a somewhat different form. The water requirement there recorded is based on total water loss and total dry matter produced by all pots, while the water requirement here given is the mean for the series of pots.

² Fontenay sand received different fertilizers and only 9 pots were used.

³ 1876 (p. 387). Conducted in open pots of 1 cubic meter capacity and 1 square meter surface. No correction was made for evaporation.

TABLE XIV.—*Effect of different soils on the water requirement of wheat, according to Marié-Davy—Continued.*

Soil employed.	Period.	Dry grain.	Water requirement, based on grain.
Montsouris plus chemical fertilizer.....	1875. ¹ Feb. 1 to July 16..	394	918
Saint-Ouen plus chemical fertilizer.....		372	956
Do.....		474	728
Gravelle plus chemical fertilizer.....		479	780
Do.....		425	837
Dornecy (brown) plus chemical fertilizer.....		262	1,385
Peat plus chemical fertilizer.....		435	841
Dornecy (red) plus chemical fertilizer.....		424	811
Vincennes plus chemical fertilizer.....		387	894
Do.....		379	966
Ivry plus chemical fertilizer.....		460	738
Do.....		379	957

¹ 1876 (p. 387). Conducted in open pots of 1 cubic meter capacity and 1 square meter surface. No correction was made for evaporation.

In 1875 commercial fertilizer was added to all pots. The differences in the water requirement in the different soils were approximately the same as during the previous year, although the water requirement was less for each soil than in 1874.

LIEBSCHER'S EXPERIMENTS.

Liebscher (1895) conducted a series of fertilizer experiments in clay and sand soils. His results are given in Table XXVI (p. 36). A comparison of the results for the two soils shows a slightly higher water requirement in the loam than in the sand, when the whole series is taken into account. The same is true also of the check plants grown without the addition of fertilizer.

KING'S EXPERIMENTS.

King (1905) used four different types of soil in his water-requirement investigations. Open pots 4 feet in diameter and 4 feet deep sunk in the ground in an open space were employed. Since the experiments were carried on at widely separated locations, differences due to climatic conditions must also be recognized. The results (Table XV) include the evaporation from the soil surface, which was unprotected. Direct-evaporation measurements were also made simultaneously in similar tanks in which no corn was grown. Taking the loss from direct evaporation as 100, the total loss from the soil tanks containing corn at the different stations in the order given in the table was 122, 84, 125, and 118. These ratios illustrate the uncertainty attending this method of measuring the water requirement of crops.

TABLE XV.—*Effect of different soils on the water requirement of corn,¹ according to King (1905, pp. 193–194.)*

Location.	Soil.	Duration.	Evaporation per square foot of soil surface per day.	Water requirement.
		<i>Days.</i>	<i>Pounds.</i>	
Goldsboro, N. C.....	Norfolk sandy loam.....	97	1.1	387
Upper Marlboro, Md.....	Norfolk sand.....	126	.98	1,152
Lancaster, Pa.....	Hagerstown clay loam.....	128	.796	474
Janesville, Wis.....	Janesville loam.....	126	.938	336

¹ The variety of corn used was Iowa Goldmine.

VON SEELHORST'S EXPERIMENTS.

Von Seelhorst (1906) measured the water requirement of rye and potatoes in open pots, using loam and sand. The results (Table XVI) show that rye has a somewhat lower requirement in loam than in sand. With potatoes, however, the results were reversed, the sand giving a slightly lower water requirement. The data are too meager to be conclusive.

TABLE XVI.—*Effect of soil type on the water requirement of rye and potatoes at Gottingen, according to Von Seelhorst. (1906, p. 316).¹*

Plant.	Sand.		Loam.	
	Mean dry matter.	Water requirement.	Mean dry matter.	Water requirement.
Rye.....	<i>Grams.</i> 306	486±15	<i>Grams.</i> 700	375
Potatoes.....	1 103	60±0	4,737	66

¹ The water requirement of potatoes is based on the green weight. Three determinations were made with each crop for sand, one determination for loam.

WIDTSOE'S EXPERIMENTS.

Widtsoe (1909) has measured the water requirement of corn and wheat at Logan, Utah, using four types of soil. Pots 24 inches in diameter and 30 inches high were employed. The College loam and Sanpete clay types were productive soils, while the sand and clay types were nonproductive. The experiments extended through a period of four years. The increased water requirement of crops when grown in nonproductive soils is clearly shown in the results, a summary of which is given in Table XVII.

TABLE XVII.—*Influence of soil texture on the water requirements of certain crops at Logan, Utah, according to Widtsoe (1909, p. 57).*

Crop.	Number of trials.				Water requirement.			
	Sand.	College loam.	Sanpete clay.	Clay.	Sand.	College loam.	Sanpete clay.	Clay.
Corn.....	11	46	12	3	561	386	408	601
Wheat.....	2	15	2	5	2,017	546	658	917
Sugar beets.....		11				497		
Peas.....		10				843		

LEATHER'S EXPERIMENTS.

Leather (1910, 1911) has investigated the water requirement of crops grown in several Indian soils. (See effect of fertilizing, Table XL, p. 52). The same crop sometimes showed a wide variation in its water requirement when grown in different soils. The water requirement of wheat grown in different unfertilized soil types in 1909-10, for example, was found to be 582, 842, and 526. Other variables enter in most cases, however, so that Table XL must be referred to for the comparisons.

CONCLUSIONS.

The water requirement, according to the data presented, is affected by the kind of soil used. The factor influencing the water requirement seems, however, to be plant food rather than the type of soil. The water requirement will be higher in a poor soil, whether it be sand or clay, than in a good soil. The data presented do not indicate that the water requirement is affected by soil texture alone, when plant food is equally available in the different soil types.

EFFECT OF CULTIVATION ON THE WATER REQUIREMENT.

SLĚSKIN'S EXPERIMENT.

Slěskin (1908) conducted an experiment to determine the effect of cultivating the soil on the growth of the sugar beet. A portion of a uniform plat was covered with a layer of cement to prevent all loss of water by direct evaporation or gain by precipitation. Seventy-two stakes were driven into the ground where the beets were to be planted and the cement flowed in around these stakes. As soon as the cement had set, the stakes were withdrawn and the holes filled with sand. The beets were planted in these holes. The remaining portion of the plat was planted to beets, allowing the same distance between plants, and was given the best of cultivation. The results shown in Table XVIII indicate clearly that more dry matter was produced by the beets grown in the covered portion than in the open plat. The reduction in water content was less in the covered soil than in the exposed soil, notwithstanding the addition to the open plat of 11 inches of water in the form of rain.

From a single pot experiment in which 3 beet plants produced 479 grams of dry matter in a pot containing 420 pounds of soil, Slėskin found the water requirement of sugar beets, exclusive of evaporation, to be 337. The beets were grown in an open pot, but by alternately covering the soil surface and leaving it exposed the evaporation was computed. This in turn was used, as a basis for computing the evaporation loss from the cultivated plat. If the computed evaporation loss is accepted, it follows that the water requirement of the beets, exclusive of evaporation, was less under the cement-covered than in the cultivated plat.

TABLE XVIII.—*Water consumption of sugar beets in cement-covered and in cultivated plats, according to Slėskin (1908).*¹

	Cement-covered plat.	Cultivated plat.
Number of beets harvested.....	59	78
Weight of beets in kilograms.....	26.9	16.1
Water added to soil by rainfall..... millimeters.....		226
Computed loss by evaporation..... do.....		247
Loss in excess of rainfall..... do.....		21
Water content of the soil at the end of experiment..... per cent.....	3.4	2.7

¹ The writers are indebted to Raphael Zon, Chief of the Office of Silvics of the Forest Service, for assistance in translating Slėskin's and Schroeder's articles.

WIDTSOE'S EXPERIMENTS.

Widtsoe (1909) has investigated the effect of shallow cultivation on the water requirement of corn (*Zea mays*). The pots, 24 inches in diameter by 30 inches high, were cultivated 48 hours after surface irrigation, and then weekly until irrigated again. The cultivation was done with a gardener's comb to a depth of 1 inch. Four pots were used for each soil type investigated, two being cultivated. Corn was grown in one cultivated and one uncultivated pot. The other two pots were without crops. The difference in the amount of water lost from the cropped and barren pot in each treatment was taken to represent the transpiration loss of the crop. The experiment was conducted for three years. The results are given in Table XIX, and show in most instances a marked reduction in the water requirement, due apparently to the cultivation.

This is a subject regarding which it is extremely difficult to obtain reliable and concordant results. The uncertainty arises in the assumption that the evaporation loss from the cropped pots is the same as from the barren pots. The pots must be left open and freely exposed, and this means a high evaporation loss. In fact, the average transpiration of all the cropped pots in Widtsoe's experiments was but 55 per cent of the total loss, the extreme values being 14 and 82 per cent.

It seems remarkable that the cultivation of the surface inch of soil should have had an appreciable influence on the actual water

requirement, and further experiments are desirable, using a larger number of pots to reduce the experimental error.

TABLE XIX.—*Effect of cultivation on the water requirement of corn, according to Widtsoe (1909, p. 19).*

Soil.	Saturation.	Treatment.	Water requirement.			Ratio, cultivated to uncultivated.			
			1902	1903	1904	1902	1903	1904	Mean.
Sand.....	15	Cultivated.....	732	281	411	1.61	.....	.....	1.61
		Uncultivated.....	454	.....	.....		
College loam.....	20	Cultivated.....	295	236	225	.56	0.62	0.25	.48 ± .09
		Uncultivated.....	523	378	908				
Sanpete clay.....	25	Cultivated.....	280	398	615	.64	.68	1.03	.78 ± .10
		Uncultivated.....	439	599	595				
Clay.....	30	Cultivated.....	582	.....	.....	.78	.....	.....	.78
		Uncultivated.....	753	468	.....			

CONCLUSIONS.

The results of Släskin and of Widtsoe lead to opposite conclusions regarding the effect of cultivation on the water requirement. Neither experiment is free from certain assumptions relative to the amount of evaporation from the soil, and consequently neither experiment can be considered as showing conclusively that cultivation has a direct effect on the water requirement independent of soil evaporation.

EFFECT OF THE SOIL MASS ON THE WATER REQUIREMENT.

HELLRIEGEL'S EXPERIMENTS.

Hellriegel (1883) measured the water requirement of red clover using culture jars of different sizes. The results are given in Table XLIX (p. 59). The differences shown in his experiments are without significance, owing to the high probable errors. A similar series dealing with barley is given in Table LII (p. 62). No consistent difference in the water requirement was found attributable to the amount of soil used.

LEATHER'S EXPERIMENTS.

Leather (1910) used in his fertilizer experiments jars ranging in capacity from 15 to 31 kilograms of soil. He states that this variation in the mass of soil used may affect the transpiration ratio 10 to 20 per cent, the smaller jars giving the higher water requirement. His results are given in Table XXXIX (p. 51) in connection with his fertilizer experiments. The writers have combined these results in Table XX, calculated with respect to the size of the jar used.¹ The mean values show with one exception that the use of the smaller jar gives a higher water requirement.

¹ The average result for each set of jars of a given size includes several fertilizer treatments. The kind of treatment and the number of jars used with each treatment are, however, uniform for a given crop and year for each size of jar, so that the results for the same crop and year are comparable.

Leather adopted for his later experiments jars containing about 50 kilograms of soil. Plants like maize and juar (jowar) were found to develop much better in these large jars than when grown in jars holding one-fourth as much soil.

TABLE XX.—*Effect of the amount of soil used on the water requirement of wheat and maize, according to Leather (1910).*

Crop.	Year.	Number of jars used.	Amount of soil used per jar.	Water requirement.
			<i>Kilograms.</i>	
Wheat.....	1906-7	12	15	722
Do.....	1907-8	6	22	454
			719	719
			37	590
Maize.....	1907	9	15	415
			21	441
			31	393

CONCLUSIONS.

Leather's data are conclusive in showing the influence of the soil mass on the water requirement. An insufficient soil mass increases the water requirement, probably as a result of an insufficient supply of plant food.

EFFECT OF FERTILIZERS ON THE WATER REQUIREMENT.

SOIL CULTURES.

LAWES'S EXPERIMENTS.

The earliest investigations regarding the effect of plant food on the water requirement were carried on with water cultures and will be considered in a subsequent section. Lawes (1850) appears to have been the first to use fertilizers in connection with soil cultures in investigating the water requirement. His results, which were obtained at the Rothamsted Station, England, are shown in Table XXI.

TABLE XXI.—*Effect of fertilizers on the water requirement of different crop plants, according to Lawes (1850, p. 54).*

Fertilizer and crop.	Dry matter. ¹	Water transpired. ¹	Water requirement.	Mean water requirement.	
				Wheat, barley, and clover.	All plants.
<i>Unmanured:</i>	<i>Grams.</i>	<i>Kilograms.</i>			
Wheat.....	29.7	7.35	247	258	248
Barley.....	30.2	7.78	258		
Clover.....	13.3	3.57	209		
Beans.....	34.8	7.27	209		
Peas.....	27.3	7.07	259		
<i>Mineral manure:</i>					
Wheat.....	28.6	6.35	222	236	227
Barley.....	32.5	8.32	256		
Clover.....	15.2	3.48	229		
Beans.....	34.8	7.64	219		
Peas.....	29.6	6.24	211		
<i>Ammoniacal and mineral manure:</i>					
Wheat.....	17.6	3.63	206	209	.....
Barley.....	20.3	5.52	272		
Clover.....	6.0	.89	148		

¹ Data recalculated to metric units.

The jars used (fig. 3) were of glass, 14 inches deep, 9 inches in diameter, and held about 42 pounds of soil. The direct evaporation was cut off by the use of a glass plate cemented to the top of the pot, a $\frac{1}{4}$ -inch hole being provided in the center for the plants. A check pot without a crop was supplied to determine the loss from evaporation through the central opening. The loss thus measured amounted to about 3 per cent of that from jars containing plants. This correction was not applied, however, Lawes believing "that the indications of this experiment should serve rather to prevent any too nice applica-

tion of the numerical results obtained in relation to the plants than as providing any available means of correcting them."

The comparison of the two series will show that the water requirement was reduced by the use of mineral manures. The plants in the series in which ammoniacal salts were used made such a poor growth that Lawes attributed little significance to the results.

MARIÈ-DAVY'S EXPERIMENTS.

Mariè-Davy (1875) investigated the effect of various fertilizers on the water requirement of wheat for grain production. The pots used were 2-liter flasks with small necks, the direct evaporation

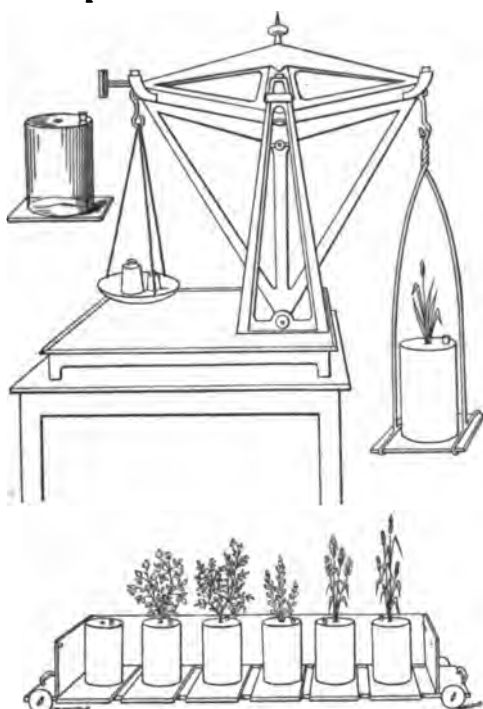


FIG. 3.—Apparat usued by Lawes (1850) in measuring the water requirment of plants.

from the soil being very small. The results of this experiment are recorded in Table XXII and represent the mean values obtained with six different soils. Each treatment lowered the water requirement as compared with the check series, which received no fertilizer.

TABLE XXII.—*Effect of fertilizers on the water requirement of wheat, according to Marié-Davy (1875, pp. 305-309).¹*

Treatment. ¹	Dry grain.	Water requirement of grain.
	Grams.	
Not fertilized.....	2.32	1,546
1.5 grams each per pot—		
CaHPO ₄ , KNO ₃ , and NaCl.....	5.40	968
KNO ₃ , (NH ₄) ₂ PO ₄ , and NaCl.....	5.52	1,181
Na ₂ HPO ₄ , K ₂ CO ₃ , and CaSO ₄	2.58	1,393
KNO ₃ , NaCl, and CaSO ₄	4.96	1,006
Soil watered with solution containing 94 milligrams (NH ₄) ₂ PO ₄ , 200 milligrams NH ₄ NO ₃ , 105 milligrams KNO ₃ , and 16 milligrams NaCl per liter.....	4.20	1,046
As above plus 10 per cent leaf mold.....	7.50	899
10 per cent leaf mold.....	4.18	988
20 per cent leaf mold.....	4.65	1,165
40 per cent leaf mold.....	9.72	981

¹ Each treatment was repeated on six different soils. (See Table XIV, p. 25.) The treatment given for this experiment by Marié-Davy (1874) does not conform exactly to the record here given. It is not clear which is correct.

HELLRIEGEL'S EXPERIMENTS.

Hellriegel (1883) carried on several experiments to determine the effect of different amounts of fertilizer on the water requirement, using open pots containing 4 kilograms of quartz sand. His results (Table XXIII) show a great decrease in the water requirement as the amount of fertilizer is increased. The water requirement was doubled by the absence of potassium and trebled by the absence of nitrogen. A correction for direct evaporation from the soil had to be made, which introduced an element of uncertainty into the results. An abnormally high water requirement would, however, be expected in the case of a plant growing in a soil which was deficient in any essential element of plant food. Its growth would be arrested, but transpiration would still go on.

TABLE XXIII.—*Effect of calcium nitrate and potash on the water requirement of barley, according to Hellriegel (1883, pp. 629-631).*

Period.	Determination.	Milligram equivalents of calcium nitrate. ¹							
		20	16	12	10	8	6	4	0
Apr. 30 to Aug. 6, 1868, 98 days	Water requirement.....	338	.....	.....	349	352	425	481	982
	Dry matter.....grams..	16.5	.....	.....	13.5	12.2	9.5	6.6	0.7
May 3 to July 24, 1869, 82 days	Water requirement.....	292	302	345	.....	347	.....	399	796±58
	Dry matter.....grams..	25.5	23.0	18.3	.....	13.9	.....	8.5	1.1±0

Period.	Determination.	Milligram equivalents of potash. ²							
		3.0	2.2	1.6	1.2	0.8	0.4	0	
Apr. 30 to Aug. 6, 1868, 98 days....	Water requirement.....	330	362	390	453	422	525	615	
	Dry matter.....grams..	20.8	18.4	17.3	15.7	15.4	10.8	6.4	

¹ Soil used: Four kilograms of quartz sand plus 2 KH₂PO₄, 1 KCl, and 1.6 MgSO₄ in milligram equivalents.

² Mean of two measurements.

³ Soil used: Four kilograms of quartz sand plus 1.6 Ca (NO₃)₂ and 1.6 MgSO₄ in milligram equivalents.

DEHÉRAIN'S EXPERIMENTS.

DehéRAIN (1892) reported experiments on the effect of different fertilizers upon the water requirement of ray-grass and clover (Table XXIV). To determine the water consumed, the amount of water which drained through the soil was deducted from the amount which fell upon the soil as rain. No correction was made for differences in the water content of the soil at the time of planting and at harvest, or for the direct loss by evaporation. The results show a lower water requirement in a manured soil than in a poor soil not manured.

TABLE XXIV.—*Effect of different fertilizers on the water requirement of ray-grass and clover, according to DehéRAIN (1892, pp. 471–473).*

Soil and treatment. ¹	Ray-grass.		Clover.	
	Dry matter.	Water requirement.	Dry matter.	Water requirement.
	<i>Grams.</i>		<i>Grams.</i>	
Good soil.....	45	630	89	322
Poor soil.....	39	662	65	454
Poor soil and K, N, and P fertilizer.....	102	* 266	72	398
Poor soil and manure water in 1890; K, N, and P fertilizer in 1891.....	64	435	99	255
Poor soil and manure water in 1890 and 1891; K, N, and P in 1891.....	65	449	95	272

¹ The water loss included evaporation. Each pot contained about 60 kilograms of soil, and the water content was assumed to be the same at the time of harvest as at the time of planting. The amount of K, N, and P was practically the same in the last three pots; the first contained N in the form of nitrate of soda and ammonium sulphate, while the last two contained organic nitrogen. The experiment continued from Apr. 7 to Sept. 4, 1891 (?).

* DehéRAIN erroneously gives 233.

KING'S EXPERIMENTS.

King (1894) investigated the effect of fertilizers on the water requirement of potatoes and corn, using large open pots. In the work with the potato, 6 galvanized-iron cylinders, 18 inches in diameter and 42 inches deep, were used. These stood above ground and were protected on the south side by a screen of boards. Each pot was watered through a 3-inch draitile set vertically in the pot against one side. The level of standing water in the pots was not allowed to rise over 6 inches from the bottom. The pots were protected at night and during rainy weather by a tent of heavy duck. The fertilized pots each received 5.3 grams of potassium nitrate before planting and the same amount the preceding year, during which time the pots were kept fallow. The results, which are given in detail in Table XXV, indicate that the use of potassium nitrate does not affect the water requirement of potatoes. In the case of corn the use of manure apparently reduced the water requirement markedly, but the result is affected with a large probable error.

TABLE XXV.—*Effect of fertilizer on the water requirement of potatoes and corn, according to King (1894, 1895).*

Pot No.	Crop.	Fertiliser.	Dry matter.	Tubers. ¹	Water.	Water requirement based on—	
						Dry matter.	Weight of tubers.
1	Potatoes ²	KNO ₃	<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>		
2			151.4	75.5	88.8	587	1,176
3			227.1	99.1	109.2	481	1,102
			204.8	97.2	106.6	517	1,086
	Mean					528±23	1,121±21
4	Potatoes ²	None	227.7	112.2	107.5	472	958
5			163.1	87.2	97.4	597	1,117
6			246.1	104.4	112.8	458	1,081
	Mean					509±35	1,062±38
2	Corn ⁴	Manured	639.1		142.7	223	
			413.9		106.5	267	
						240±14	
1	Corn ⁴	Not manured	618.7		143.5	232	
			174.8		78.4	448	
						390±91	

¹ From King's data (1895, p. 246).² King (1895, pp. 242, 243). The variety used was Alexander's Prolific.³ King gives 497 for this ratio, which is evidently an error.⁴ King (1894, p. 157). A flint variety was used. The amount of manure used is not stated. It is described as "a dressing," placed 5 inches below the surface.⁵ King gives 223 for this value, which from his data is evidently an error; the ratio was apparently taken in inverse order.

LIEBSCHER'S EXPERIMENTS.

Liebscher (1895) measured the water requirement of oats as affected by different fertilizers. The pots, which were open and contained from 9 to 11 kilograms of soil, were equipped with Liebscher's air-circulation apparatus (1895, p. 144). This consists of a half cylinder of zinc located at the bottom of the pot, with the opening on the under side. A zinc tube 1 centimeter in diameter is soldered to each end of the half cylinder and rises upward along the inner wall of the pot. One tube ends at the top of the pot; the other rises 15 centimeters above the upper edge. The pot is so oriented that the longer tube is on the south side, where it becomes strongly heated in the sun, and thus induces an air circulation through the half cylinder below. No statement could be found regarding the method of protecting the pots from rain, or as to whether the water was added through the ventilating apparatus or to the surface soil. The results are given in Table XXVI. These results are as a whole consistent and conclusive. The check series, both with clay and sand, gave a higher water requirement than any other series, while the complete fertilizer (KNP) gave the lowest water requirement. Phosphorus alone gave better results in the clay than in sand, while potassium gave a higher requirement than either nitrogen or phosphorus used

singly. In the clay soil phosphorus and nitrogen combined gave a water requirement lower than either phosphorus and potassium or potassium and nitrogen. In the sand phosphorus and nitrogen gave the same result as potassium and nitrogen, while potassium and phosphorus gave a somewhat higher water requirement.

TABLE XXVI.—*Effect of different fertilizers on the water requirement¹ of oats at Gottingen, according to Liebscher (1895, p. 211).*

		Water requirement, using—								
		K	N	P	KNP	Check.	KN	KP	PN	Mean.
Clay, 9,160 grams; water, 2,210 grams..	Dry matter, grams.	32.1	45.6	43.2	123.2	² 32.1	42.2	42.6	122.8	278
	Water require- ment.	344±9	311±1	270±7	173±3	349±9	319±7	264±2	177±2	
Sand, 11,700 grams; water, 1,740 grams..	Dry matter, grams.	35.2	129.7	35.7	149.3	34.0	133.3	36.0	139.7	251
	Water require- ment.	312±8	194±2	307±5	178±1	332±7	192±2	290±6	192±1	

¹ Probable errors are computed by the writers from Liebscher's data; three pots were used in each determination. Three applications of fertilizer were made during the season, the amounts applied per pot each time being as follows: 0.475 grams of N; 0.482 grams of P_2O_5 ; and 0.906 grams of K_2O .

² Liebscher gives 32.7, which is evidently an error.

MAERCKER'S EXPERIMENTS.

Maercker (1896) investigated the effect of various potassium fertilizers and of sodium chlorid on the water requirement of white mustard. As a source of potassium he used kainit (a hydrous magnesium sulphate containing potassium chlorid) and carnallit (a hydrous chlorid of magnesium and potassium). The soil used was sand with an admixture of 2.5 per cent of peat. The capacity of the pots is not stated, but was probably small, 6 kilograms of soil being used in other fertilizer experiments with mustard. The pots were not covered, and check pots without plants were not used. The summary of results (Table XXVII) shows that all the fertilizers used, including sodium chlorid, reduced the water requirement.

TABLE XXVII.—*Effect of potassium and sodium salts on the water requirement of white mustard,¹ according to Maercker (1896, p. 21).*

Fertilizer per hectare.	60 per cent of moisture-holding capacity (18 per cent water).		20 per cent of moisture-holding capacity (8 per cent water).		Mean water requirement.
	Dry matter.	Water requirement.	Dry matter.	Water requirement.	
Without potash.....	Grams. 24.4	357	Grams. 12.6	282	320
1,000 kilograms kainit.....	25.5	309	12.1	296	298
2,000 kilograms kainit.....	25.3	305	9.5	143	224
2,000 kilograms carnallit.....	24.0	333	12.2	200	267
2,000 kilograms NaCl.....	16.6	321	9.9	197	259
Mean.....		325		210	

¹ One pot only was used for each treatment. These data are also found in Maercker, 1896a (p. 15).

SCHROEDER'S EXPERIMENTS.

Schroeder (1896) used the same nutrient solution previously employed by Hellriegel. The results of his experiments given in Table IV (p. 14) do not show a decrease in the water requirement with an increase of concentration of the nutrient solution.

VON SEELHORST'S EXPERIMENTS.

Von Seelhorst (1899) has investigated the effect of different nutrients upon the water requirement of oats. His first experiments, the results of which are given in Table XXVIII, were made in zinc cans holding about 20 kilograms of earth. Two pots were used for each treatment, but the data for the individual pots are not given, so that it is not possible to calculate the probable error. Each fertilizer treatment was carried on with three different soil-moisture contents, so that the mean water requirement as given in the eighth column of the table represents the average of 6 pots in each case. It is interesting to note that the addition of potassium had no effect on the water requirement, phosphorus caused only a slight reduction, while a marked reduction accompanied the use of nitrogen, both alone and in combination.

In another experiment Von Seelhorst compared the water requirement of oats with the same crop following mustard. Two series of fertilized pots were prepared, one of which was planted to mustard, while the other remained fallow. The next year both series were planted to oats without additional fertilizer. These results, also given in Table XXVIII, are apparently limited to a single pot for each treatment. The introduction of the mustard crop increased the water requirement of the oat crop 67 per cent. The oats following fertilizer showed a slight reduction in the water requirement, due to the use of phosphorus, while the oats following mustard showed the greatest reduction with the nitrogen fertilizers.

TABLE XXVIII.—*Effect of different fertilizers and crop sequence on the water requirement of oats, according to Von Seelhorst (1899, pp. 372, 376-377).*

Fertiliser. ¹	Water content, in terms of moisture-holding capacity. ²						Crop-sequence experiment. ³				
	49 to 54 per cent.		59 to 64 per cent.		64 to 74 per cent.		Mean water re-quire-ment.	Oats.		Oats follow- ing mustard.	
	Dry mat-ter.	Water re-quire-ment.	Dry mat-ter.	Water re-quire-ment.	Dry mat-ter.	Water re-quire-ment.		Dry mat-ter.	Water re-quire-ment.	Dry mat-ter.	Water re-quire-ment.
	<i>Grams.</i>		<i>Grams.</i>		<i>Grams.</i>			<i>Grams.</i>		<i>Grams.</i>	
K.....	40.2	290	51.2	261	47.9	302	294	62.5	291	17.5	542
N.....	55.2	230	67.5	243	75.5	231	235	62.4	363	38.4	343
P.....	38.5	268	49.9	290	54.4	283	280	72.6	255	15.3	584
KNP.....	49.9	225	86.7	237	95.1	232	231	90.3	258	21.2	403
Check.....	39.6	260	48.8	313	52.6	307	293	67.4	280	18.1	506
KN.....	41.3	227	66.9	225	92.9	222	225	79.3	277	31.3	350
KP.....	41.3	247	52.9	291	51.5	306	281	76.0	249	16.8	535
PN.....	46.8	236	84.0	220	108.3	216	224	91.5	254	28.3	457
Mean.....	.....	235	.....	264	.....	262	.....	.....	278	.....	465

¹ P represents 1 gram of phosphoric acid; K, 1 gram of potash; N, 1 gram of nitrogen.² Harvested just before the milk stage; 20 kilograms per pot. Two pots were used in each treatment, but the data for the individual pots are not given.³ Eleven kilograms of earth per pot.

WILMS'S EXPERIMENTS.

Wilms (1899) conducted a somewhat more elaborate experiment with early potatoes. The results of this experiment are given in Table XXIX, the water requirement being expressed in terms of the green weight. The zinc pots in which the experiments were conducted held about 15 kilograms of soil. The surface soil was left dry throughout the experiment, water being added below the surface through Liebscher's aerating device. All tubers under 5 grams in weight were discarded and the ratio is expressed in the green weight of the remaining tubers. An analysis of the soil preparatory to the experiment showed it to be rather poor in phosphoric acid, and 1 gram of phosphoric acid (P_2O_5) was therefore added in the form of ammonium calcium phosphate to each pot. The mean water requirement for each treatment shows that the various salts reduced the water requirement very slightly. The low yield and high water requirement when potassium chlorid was used is attributed to the fact that this salt was impure, containing about 4 per cent of potassium chlorate.

TABLE XXIX.—*Effect of different fertilizers on the water requirement of potatoes,¹ according to Wilms (1899, pp. 288–289).*

Fertilizer.	Water content, in terms of moisture-holding capacity.						Mean water requirement.
	33 per cent.		58 per cent.		80 per cent.		
	Tubers.	Water requirement.	Tubers.	Water requirement.	Tubers.	Water requirement.	
	<i>Grams.</i>		<i>Grams.</i>		<i>Grams.</i>		
Check.....	123.5	40 ± 0	178.4	48 ± 2	196.5	57 ± 1	48
KCL.....	38.7	55 ± 3	47.9	88 ± 6	41.8	138 ± 5	94
K ₂ SO ₄	144.7	36 ± 2	190.2	47 ± 2	246.4	52 ± 1	45
KNO ₃	215.8	37 ± 1	30.4	51 ± 1	380.5	53 ± 0	47
K ₂ CO ₃	137.2	35 ± 2	204.1	44 ± 1	240.9	49 ± 0	43
NaCl.....	137.4	36 ± 0	192.7	43 ± 1	192.8	57 ± 0	45
Na ₂ SO ₄	138.5	36 ± 2	179.7	44 ± 0	181.4	62 ± 1	47
NaNO ₃	178.4	40 ± 0	279.2	49 ± 2	311.0	54 ± 1	48
Na ₂ CO ₃	134.6	39 ± 0	183.3	46 ± 0	203.7	53 ± 1	46
MgCl ₂	124.5	39 ± 0	168.8	48 ± 0	205.0	55 ± 1	47
MgSO ₄	131.2	39 ± 1	185.4	47 ± 1	206.2	57 ± 2	48
MgCO ₃	130.0	39 ± 1	192.8	46 ± 0	193.3	61 ± 2	49
Mean.....		39		50		62	

¹ The water requirement, based on the green weight of the tubers only, is recalculated from the data. Two open pots containing about 17 kilograms of soil were used for each determination. The amounts of the various salts were equivalent to 3 grams of K₂O, 3 grams of Na₂O, and 3 grams of MgO. The variety used was Paulsen's July.

² Wilms gives 197.3, which appears to be an error.

DASZEWSKI'S EXPERIMENTS.

Daszewski (1900) determined the dry weight of some of the potatoes grown by Wilms and expressed the water requirement in terms of the dry weight of the tubers. The results are given in Table V. From these results it would appear that the use of potassium nitrate and potassium sulphate reduced the water requirement slightly.

WILFARTH AND WIMMER'S EXPERIMENTS.

Wilfarth and Wimmer (1902), using the results obtained in connection with an extensive series of fertilizer experiments, have determined the effect of varying amounts of potash and other salts upon the water requirement of various crops. The experiments were for the most part made in small, open pots, containing only a few kilograms of soil. Each experiment was duplicated, but in calculating the water requirement the results were combined as if only a single pot of double the capacity had been used. This method does not show to what extent the duplicate determinations agree. Accordingly, the water requirement for each individual pot has been recalculated by the writers and the probable error of the mean computed. One determination only was made where no probable error is given. In cases where more than two determinations were made the treatment was not exactly the same for all pots of the series. The pots received the amounts of fertilizer indicated in Table XXX and XXXI, but for a full report of the treatment the reader is referred to the original publication. These results include meas-

urements made with potatoes, tobacco, buckwheat, mustard, chicory, and oats.

TABLE XXX.—*Effect of different amounts of potash on the water requirement of crops, according to Wilfarth and Wimmer (1902, pp. 10-15).*

Crop and period.	Soil, etc., per pot.	Fertilizer per pot.		Mean dry matter.	Mean water requirement.
		K ₂ O.	N.		
Potatoes: ¹ 1897.....	Sand and turf.....	Grams.	Grams.	Grams. .....	.....
		0.094	1.400	20.1	717±3
		.188	1.400	28.7	504±27
		.940	2.388	36.7	422±11
		1.504	2.388	76.9	291±4
	{Sand, 3,760 grams; turf, 240 grams; water, 1,000 grams.	1.504	2.388	102.8	254±2
		.188	1.680	35.0	453±15
		1.504	2.380	99.2	257±5
		4.700	2.800	114.0	230±15
		.....	2.450	39.8	637±30
Apr. 29 to Sept. 8, 1897 ²	{Sand, 6,070 grams; turf, 455 grams; water, 1,800 grams.	.141	2.450	45.6	596±5
		.282	2.450	56.4	528±49
		.282	3.920	65.3	507±32
		.846	3.920	100.3	396±12
		1.692	3.920	128.3	339±7
	{Sand, 6,070 grams; turf, 455 grams; water, 1,800 grams; water increased Aug. 24 to 2,010 grams.	.....	1.120	33.8	1,345±55
		.282	1.120	50.5	878±72
		.....	2.800	50.3	502±76
		.282	2.800	82.8	283±4
		.846	2.800	121.5	267±10
May 2 to Sept. 13, 1898 ³	{Sand, 6,070 grams; turf, 455 grams; water, 1,800 grams; water increased July 5 to 2,250, and July 18 to 2,375 grams.	1.800	2.800	165.1	196±5
		4.700	2.800	176.4	260±2
		3.290	2.940	199.3	232±6
		6.580	2.940	214.4	*214±2
		9.400	2.940	188.8	235±14
May 5 to Sept. 13, 1899 ⁴	{Sand, 6,070 grams; turf, 455 grams; water, 1,780 grams; water increased July 5 to 2,250, and July 18 to 2,375 grams.	.....	1.400	17.0	908±41
		.0235	1.400	23.7	749±5
		.094	2.380	65.7	446±19
		.940	2.380	83.9	372±2
		2.585	2.380	75.7	*403±5
Apr. 25 to Sept. 15, 1900 ⁵	{Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams.	.....	2.030	14.4	893±13
		.0235	2.030	22.1	626±0
		.094	2.030	26.8	665±30
		.188	3.500	29.3	556±12
		.564	3.500	52.7	443±4
Apr. 6 to Aug. 20, 1897 ⁶	{Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams.	2.115	3.500	87.0	419
		2.820	3.500	83.2	434
		.....	1.120	20.3	696±3
		.282	1.120	52.4	457±28
		.0235	2.520	29.4	422±33
Apr. 21 to Sept. 17, 1898 ⁷	{Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams; water increased July 13 to 1,370 grams.	.282	2.520	55.4	382±24
		.846	2.520	85.2	300±11
		1.880	2.520	84.5	297±5
		2.820	2.520	93.3	273±2
		.....	2.520	29.4	422±33
Apr. 24 to Oct. 5, ⁸ 1899 ⁹	{Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams; water increased July 13 to 1,370 grams.	.282	2.520	55.4	382±24
		.846	2.520	85.2	300±11
		1.880	2.520	84.5	297±5
		2.820	2.520	93.3	273±2
		.....	2.520	29.4	422±33

¹ Computed from data of Wilfarth and Wimmer (1902, pp. 10-15). Duplicate determinations were made except where probable error is not given, in which case only one determination was made. (See Wilfarth and Wimmer, 1902, pp. 8-9, form A, for a complete record of the fertilizers used with potatoes.) Tops, tubers, and roots are included. On page 13, in columns 17 and 18, are errors.

² Mühlhäuser variety used.

³ Geheimrat Thiel variety used.

⁴ Mean of eight determinations.

⁵ Computed from data of Wilfarth and Wimmer (1902, pp. 44-51). Duplicate determinations were made except where no probable error is given, in which case only one determination was made. The dry matter includes roots. (See Wilfarth and Wimmer, 1902, pp. 34-35, form B, for a complete record of the fertilizers used with tobacco.)

⁶ *Nicotiana rustica* variety used.

⁷ Ten determinations.

⁸ *Nicotiana tabacum* (Virginia) variety used.

⁹ The leaves were harvested at different times and the flower buds cut off.

TABLE XXX.—*Effect of different amounts of potash on the water requirement of crops, according to Wilfarth and Wimmer (1902, pp. 10-15)—Continued.*

Crop and period.	Soil, etc., per pot.	Fertilizer per pot.		Mean dry matter.	Mean water requirement.
		K ₂ O.	N.		
White mustard: ¹		Grams.	Grams.	Grams.	
Apr. 12 to July 13, 1897.....	{ Sand, 2,350 grams; turf, 150 grams; water, 635 grams.	0.047 .094 .188 .376	0.700 .700 .700 .700	14.1 25.6 35.8 37.3	848±26 651±6 611±30 498±21
Apr. 19 to July 26, 1900.....	{ Sand, 2,500 grams; turf, 160 grams; water, 665 grams.	.376 .084 .047 .376 .047 .1175 .564	.084 .084 .224 .224 .700 .700 .700	5.3 4.2 11.6 12.2 13.4 21.6 26.5	1,133±179 1,193±8 741±9 718±14 807±8 659±50 562±10
Buckwheat: ²					
Apr. 14 to July 16, 1897.....	{ Sand, 4,000 grams; water, 700 grams.	.047 .141	.700 .700	5.1 13.9 23.2	920 494±12 417±10
Apr. 23 to July 26, 1900.....	do.....	.112 .564 .047 .564 .420 .047 .141 .564	.700 .112 .112 .252 .252 .420 .420 .420	6.5 11.2 12.3 19.2 8.8 14.6 14.6 30.4	906±83 709±3 748 554±25 950±9 776±4 772±0 415±18
Chicory, Magdeburg: ⁴					
Apr. 28 to Nov. 17, 1900.....	{ Sand, 4,465 grams; turf, 285 grams; water, 1,190 grams.	.0235 3.290 .282 3.290 .0235 .282 .846 3.290	.140 .140 .280 .280 1.680 1.680 1.680 1.680	14.5 12.1 28.4 30.0 16.3 52.2 77.4 83.2	608±68 790±55 455±22 405±49 679±59 331±33 254±12 217±5
Oats: ⁵					
Apr. 23 to Aug. 6, 1900.....	{ Sand, 4,000 grams; water, 700 grams.	.084 .376 .047 .376 .047 .1175 .376	.084 .084 .224 .224 .420 .420 .420	7.1 8.8 12.9 18.8 7.9 14.0 18.8	1,095±27 948±20 813±16 674±6 1,017±26 806±0 688±10

¹ Computed from data of Wilfarth and Wimmer (1902, pp. 64-65). Duplicate determinations were made. The dry matter includes the roots. (See Wilfarth and Wimmer, 1902, pp. 62-63, form D, for a complete record of the fertilizers used with mustard.)

² Computed from data of Wilfarth and Wimmer (1902, pp. 54-55). Duplicate determinations were made except where no probable error is given, in which case only one determination was made. The dry matter includes the roots. (See Wilfarth and Wimmer, 1902, pp. 52-53, form C, for a complete record of the fertilizers used with buckwheat.)

³ Mean of four determinations.

⁴ Computed from data of Wilfarth and Wimmer (1902, pp. 74-75). Duplicate determinations were made. The dry matter includes the roots. (See Wilfarth and Wimmer, 1902, pp. 72-73, form E, for a complete record of fertilizers used with chicory.)

⁵ Computed from data of Wilfarth and Wimmer (1902, pp. 82-83). Duplicate determinations were made. The dry matter includes the roots. (See Wilfarth and Wimmer, 1902, p. 81, form F, for a complete record of the fertilizers used with oats.)

The effect of different amounts of potash on potatoes is shown in Table XXX. The first series of experiments conducted in 1897 and those conducted in 1898 show without exception a reduction in the water requirement when potash is increased. The second series in 1897 is included here, but since both nitrogen and potash were increased the lower water requirement can not be attributed to potash alone. The results of 1899 and 1900 showed first a decrease and later an increase in the water requirement when the potash was increased.

In general the experiments show a consistent and decided decrease in the water requirement of potatoes when moderate amounts of potash are added, the water requirement decreasing gradually with the increase in potash until about 0.06 per cent has been added. The addition of potash in excess of this amount increases the water requirement.

The effect of different amounts of potash on the water requirement of tobacco is also shown in Table XXX. Here, as in the experiments with potatoes, the water requirement gradually decreases with the gradual increase of potash. The lowest water requirement occurs with about 0.04 per cent of potash.

The results with white mustard show a decrease in water requirement with an increase in potash. Similar results are shown for buckwheat, for Magdeburg chicory, and for oats (Table XXX).

The results of Wilfarth and Wimmer's experiments are consistent and show practically without exception a gradual decrease in the water requirement when potash is added in small amounts. If too much potash is added (more than 0.04 to 0.06 per cent) the water requirement is again slightly increased.

The effects of different amounts of nitrogen and sodium on the water requirement of potatoes, tobacco, buckwheat, mustard, chicory, and oats are shown in Table XXXI. As a rule, the addition of nitrogen lowers the water requirement of each crop considered. The exceptions show a difference so small as to be well within the limit of probable error. Except in the case of buckwheat, oats, and chicory, the addition of sodium did not consistently lower the water requirement. In some cases it seemed to increase the water requirement, as in the experiments with potatoes when potash was also added.

TABLE XXXI.—*Effect of different amounts of nitrogen and sodium on the water requirement of crops,¹ according to Wilfarth and Wimmer.*

Crop and period.	Soil per pot.	Fertilizer per pot.			Mean dry matter.	Mean water requirement.
		K ₂ O	Na ₂ O	N		
		Grams.	Grams.	Grams.	Grams.	
Potatoes: May 5 to Sept. 13, 1899.	Sand, 6,670 grams; turf, 455 grams; water, 1,800 grams; water increased Aug. 24 to 2,010 grams.	.....	.....	0.560	27.0	1,720
		.....	.....	1.120	33.8	1,345±55
		.....	0.620	1.120	33.7	1,310±137
		.....	.....	2.800	50.3	502±76
		0.282	.....	1.120	50.5	878±72
		.282	.....	2.100	68.7	648±15
		.282	.620	2.100	69.5	662±2
		.282	.....	2.800	82.8	283±4
		.846	.....	1.820	108.3	407±11
		.846	.....	2.800	121.5	267±10
		.846	1.240	2.800	105.3	453±6
	
Apr. 25 to Sept. 15, 1900.	Sand, 6,670 grams; turf, 455 grams; water, 1,780 grams; water increased July 5 to 2,255 grams, and July 18 to 2,375 grams.	.....	.....	1.750	48.6	508±25
		.....	3.100	1.750	47.3	496±1
		.846	.....	2.240	97.5	332±6
		.846	3.100	2.240	96.4	336±23

¹ Computed from data of Wilfarth and Wimmer (1902), as follows: Potatoes, pp. 10-15; tobacco, pp. 44-51; buckwheat, pp. 54-55; mustard, pp. 64-65; chicory, pp. 74-75; oats, pp. 82-83. Determinations were in duplicate except where no probable error is given, in which case only one determination was made.

TABLE XXXI.—*Effect of different amounts of nitrogen and sodium on the water requirement of crops, according to Wilfarth and Wimmer—Continued.*

Crop and period.	Soil per pot.	Fertilizer per pot.			Mean dry matter.	Mean water requirement.
		K ₂ O	Na ₂ O	N		
Tobacco: Apr. 6 to Aug. 20, 1897.	Sand, 3,760 grams; turf, 240 grams; water, 1,000 grams.	Grams.	Grams.	Grams.	Grams.	
		1.410	.....	2.380	83.9	372±2
		1.410	2.790	2.380	19.8	322±5
		2.585	1.302	2.380	93.3	347±8
	Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams.	2.585	1.457	2.380	87.9	358±5
		.188	.....	2.030	26.8	665±20
		.188	.....	3.500	29.3	556±12
		.0235	.....	.560	18.0	709±10
	Sand, 4,445 grams; turf, 305 grams; water, 1,200 grams; water increased July 13 to 1,370 grams.	.0235	.620	.560	20.5	669±20
		.0235	.....	1.120	20.3	696±3
		.0235	.....	2.520	28.4	492±23
		.282	.....	1.120	52.4	457±28
		.282	.620	1.120	57.2	372±8
		.282	.....	2.100	57.4	363±3
		.282	.....	2.520	55.4	382±24
		.846	.....	1.820	82.4	288±4
		.846	.620	1.820	80.6	302±3
		.846	.....	2.520	85.2	300±11
Buckwheat: Apr. 23 to July 26, 1900.	Sand, 4,000 grams; water, 700 grams.	.....	.....	.112	6.5	996±83
		.....	.....	.420	8.8	950±9
		.....	.620	.420	9.8	642±29
		.047	.....	.252	12.3	746
		.047	.....	.420	14.6	776±4
		.047	.620	.420	12.0	575±4
		.564	.....	.112	11.2	709±3
		.564	.....	.252	19.2	554±25
		.564	.....	.420	30.4	415±18
Mustard: Apr. 19 to July 26, 1900.	Sand, 2,500 grams; turf, 160 grams; water, 665 grams.	.....	.....	.084	5.3	1,133±179
		.....	.....	.700	13.4	807±8
		.047	.....	.224	11.6	741±9
		.047	.....	.700	21.6	659±50
		.376	.....	.084	4.2	1,193±8
		.376	.....	.224	12.2	718±14
		.564	.....	.700	29.1	500±8
		.564	.744	.700	27.0	493±17
Chicory: Apr. 28 to Nov. 17, 1900.	Sand, 4,465 grams; turf, 285 grams; water, 1,190 grams.	.0235	.....	.140	14.5	698±68
		.0235	.....	1.680	16.3	679±59
		.0235	1.550	1.680	23.2	512±81
		.282	.....	.280	28.4	455±22
		.282	.....	1.680	52.2	331±33
		.282	1.550	1.680	49.7	298±0
		.846	.....	1.680	77.4	254±12
		.846	1.550	1.680	77.7	232±17
		3.290	.....	.140	12.1	790±55
		3.290	.....	.280	30.0	405±49
		3.290	.....	1.680	83.2	217±8
Oats: Apr. 23 to Aug. 6, 1900.	Sand, 4,000 grams; water, 700 grams.	.....	.....	.084	7.1	1,095±27
		.....	.....	.420	7.9	1,017±26
		.....	.620	.420	9.6	949±33
		.047	.....	.224	12.9	813±16
		.047	.....	.420	14.0	806±0
		.047	.620	.420	22.2	586±8
		.1175	.....	.420	18.8	688±10
		.1175	.620	.420	27.7	523±9
		.376	.....	.084	8.8	948±20
		.376	.....	.224	18.8	674±6
		.376	.....	.420	22.3	615±2

VON SEELHORST AND BÜNGER'S EXPERIMENTS.

Von Seelhorst and Bünger (1907) measured the water requirement of summer wheat grown in pots containing 12 kilograms of soil. Different fertilizers were used. The results are given in Table XXXII. The experiments were conducted in open pots. It is not clear from Von Seelhorst and Bünger's description of their experiments whether the data as given in the table have been corrected for evaporation from the soil. The fertilizer scheme followed is stated to be the same as that used in one of the experiment fields at Gottingen, but details are not given. Both the increased yield and lower water requirement accompanying the use of nitrogen indicate that nitrogen is the deficient food element in the soil used in this experiment. The higher mean water requirement obtained with five plants in a pot as compared with a single plant also indicates a deficient supply of some food element.

TABLE XXXII.—*Effect of different fertilizers on the water requirement of summer wheat,¹ according to Von Seelhorst and Bünger (1907, p. 247).*

Fertiliser.	Low water content.				High water content.				Mean water requirement.
	One plant.		Five plants.		One plant.		Five plants.		
	Dry matter.	Water requirement.	Dry matter.	Water requirement.	Dry matter.	Water requirement.	Dry matter.	Water requirement.	
K.....	10.6	229	13.1	269	14.1	467	15.3	.....	.....
N.....	24.4	217	31.9	255	49.6	227	72.5	255	239
P.....	9.3	197	12.9	240	12.3	405	15.9	368	303
KNP.....	27.7	222	36.0	233	.....	.....	74.1	257	.....
Check.....	10.5	217	12.5	272	13.2	309	12.5	.....	.....
KN.....	28.7	217	41.2	225	56.2	259	68.5	278	245
KP.....	10.8	197	13.9	261	12.5	344	16.6	362	291
PN.....	21.7	211	39.4	228	46.2	237	76.2	267	236
CaKNP.....	26.5	227	40.3	236	52.6	240	82.6	245	237
Mean.....	18.9	215	26.7	247	.....	.....	48.2	.....	.....
Mean water requirement for all but K, KNP, and check.....	.....	211	.....	241	.....	285	.....	296	.....

¹ The pots contained 12 kilograms of loam soil.

OHLMER'S EXPERIMENTS.

Ohlmer (1908) measured the effect of different fertilizers on the water requirement of squarehead wheat. Open pots were used and no correction was made for evaporation from the soil. The results (Table XXXIII) show a reduction in the water requirement when nitrogen is added. The addition of phosphorus, potash, and calcium slightly increased the water requirement.

TABLE XXXIII.—*Effect of different fertilizers on the water requirement of squarehead wheat,¹ according to Ohlmer (1900, p. 157).*

Fertiliser.	Water content, in terms of moisture-holding capacity.			
	45 per cent.		70 per cent.	
	Dry matter.	Water requirement.	Dry matter.	Water requirement.
	<i>Grams.</i>		<i>Grams.</i>	
K.....	18.8	277	22.2	304
N.....	57.5	219	105.2	248
P.....	19.2	282	23.1	294
KNP.....	69.5	209	121.9	251
KN ₂ P.....	74.4	208	130.8	242
Check.....	19.4	274	22.8	281
KN.....	72.2	204	120.0	246
KP.....	20.5	248	21.7	328
PN.....	64.8	216	111.3	265
Ca.....	17.8	282	21.5	320
CaKNP.....	68.5	242	120.4	256
Mean.....		242		276

¹ Four pots for each determination; probably 20 kilograms of loam per pot. The fertilizer was added per pot as follows: K=1 gram K₂O as K₂CO₃; N=1.5 grams N as NaNO₃; N₂=1.5 grams N as (NH₄)₂SO₄; P=1 gram P₂O₅ as CaH₄(PO₄)₂; Ca=5 grams CaCO₃.

PREUL'S EXPERIMENTS.

Preul (1908) used a good and a poor soil in connection with an investigation of the effect of the soil-moisture content on the water requirement. The poor soil was simply a mixture of the good soil with heath sand. The results of his experiments (Table VIII, p. 19) show a consistently lower water requirement for the wheat grown in the good soil, in which the average water requirement was approximately 80 per cent of that of the wheat grown in the poor soil.

SUMMARY OF EXPERIMENTS AT GOTTINGEN, GERMANY.

Several of the experiments heretofore cited were carried on at Gottingen under comparable conditions. The results of the experiments are summarized and combined in Table XXXIV and show that, with the exception of the potash series, the unfertilized check gave the highest value. Nitrogen reduced the water requirement decidedly, whether alone or in combination with phosphorus or potash. The lowest results have been obtained by a combination of potash, nitrogen, and phosphorus. In these results the evaporation from the soil has apparently been included with the transpiration, and the water requirement calculated on the basis of the air-dry weight of the crop.

TABLE XXXIV.—*Effect of various fertilizers on the water requirement of oats and wheat at Gottingen, Germany, according to different investigators.*

Crop.	Soil.	Soil moisture.	Notes.	Water requirement with—								
				K	N	P	KNP	Check	KN	KP	PN	
Oats ¹ ...	<i>Kilograms.</i>											
	(Clay, 9.16...	2.21 kilograms...	3 pots.....	344±9	311±1	270±7	173±3	349±9	319±7	264±2	177±2	
	(Sand, 11.7...	1.74 kilograms...	do.....	313±8	194±2	2307±5	178±1	332±7	192±2	290±6	192±1	
Do ² ...	Earth, 20....	49 to 54 ³.....	.....	290	230	268	225	260	227	247	236
		59 to 64 ³.....	.....	291	243	290	237	313	225	291	220
	Earth, 11....	64 to 74 ³.....	.....	302	231	283	232	307	222	306	216
		.....	.....	291	363	255	258	280	277	249	254
Wheat ⁴	Loam, 12....	.....	.....	542	343	584	403	506	350	535	457
		Low water content.	1 plant per pot.	229	217	197	222	217	217	197	211	
		.....	5 plants per pot.	269	255	240	233	272	225	261	228
		High water content.	1 plant per pot.	467	227	405	.....	309	259	344	237
Do ⁵ ...	Loam, 20 (?)	.....	.....	.....	255	368	267	.....	278	362	267
		45 ³	4 pots.....	277	219	282	209	274	204	248	216	
		70 ³	do.....	304	248	294	251	281	246	328	265	
Mean water requirement ⁶				314	259	297	238	308	246	294	243	

¹ Liebacher, 1895, p. 211.² Von Seelhorst, 1899, p. 372.³ Percentage of moisture-holding capacity.⁴ Von Seelhorst and Büniger, 1907, p. 247.⁵ Ohlmer, 1906, p. 157.⁶ Mean for all determinations except Von Seelhorst and Büniger's high water content series.

WIMMER'S EXPERIMENTS.

Wimmer (1908) published the results of extended experiments conducted by a large number of collaborators. The data on the effect of potash and nitrogen on the water requirement are given in Tables XXXV and XXXVI.

Glass pots 33 centimeters high with an upper diameter of 21 centimeters and a lower diameter of 19 centimeters were used. These pots were left open and the combined transpiration and evaporation determined. Apparently no attempt was made to correct for evaporation from the soil surface. The plants were grown to maturity. Many details of the experiment are given in the tables and need not be repeated here.

The effect of potash (Table XXXV) is much less evident than in the work of Wilfarth and Wimmer (1902), already discussed (p. 39). Even in the soils showing the lowest content of potash the addition of potash did not lower the water requirement. None of the soils were poor in potash.

The addition of nitrogen (Table XXXVI) lowered the water requirement with most plants. In Juetrichau sand the high probable error, as well as the small amount of dry matter produced, lead one to disregard these data in discussing the results as a whole.

TABLE XXXV.—*Effect of potash on the water requirement of plants,¹ according to Wimmer.*

Crop and period.	Soil used.				K ₂ O added per pot.	Soil moisture.	Mean dry matter.	Water requirement.
	Plat.	Previous fertilization.	Potash and soda by analysis.	Per pot.				
Ray-grass: ² June 1 to Oct. 18, 1904.	B 1	No potash, 1891 to 1904.. Stable manure, 1891 to 1895. Green manure, 1901.	Per cent.	Grms.	Grms.	Per ct.	Grms.	
			0.247 K ₂ O	6,766	.....	15	66.9	302±1
			.045 Na ₂ O		0.155	15	63.6	301±39
					.776	15	69.9	266±3
	B 3	None, 1891 to 1904.....				18	76.7	307±21
					.155	18	73.5	343±34
					.776	18	80.3	316±4
						15	71.5	302±8
	B 5	No potash, 1891 to 1904.. Stable manure, 1891 to 1895. Green manure, 1901.	.251 K ₂ O	6,903	.....	15	66.3	322±22
			.050 Na ₂ O		.155	15	68.7	324±3
					.776	15	84.5	283±5
					.155	18	85.9	276±11
Apr. 17 to Sept. 26, 1905.	B 3	None, 1901 to 1905.....			.776	18	72.9	312±27
			.295 K ₂ O	6,791	.....	15	57.0	365±14
			.090 Na ₂ O		.155	15	60.8	386±55
					.776	15	67.8	290±17
	F 3	.....do.....				18	69.4	367±1
					.155	18	66.6	376±5
					.776	18	78.4	283±11
			.244 K ₂ O	7,919	.....	15	92.4	313±4
	H 3	No potash, 1902 to 1905..	.044 Na ₂ O		.155	15	93.8	306±21
					.776	15	92.5	310±7
						18	95.6	333±17
					.155	18	98.7	336±1
Chicory: ³ May 3 to Nov. 12, 1906.	F 3	.....do.....			.776	18	100.4	350±16
			.239 K ₂ O	7,768	.....	15	90.0	305±13
			.039 Na ₂ O		.155	15	88.4	319±32
					.776	15	90.0	312±17
	H 3	No potash, 1902 to 1905..				18	113.4	290±4
			.221 K ₂ O	7,344	.....	15	104.3	303±7
			.061 Na ₂ O		.155	18	102.1	311±7
					.776	15	80.2	341±32
	B 5	None, 1891 to 1904..... Stable manure, 1891 to 1895. Green manure, 1901.				15	84.7	311±11
			.259 K ₂ O	7,000	.....	15	96.2	263±9
			.068 Na ₂ O		.155	18	90.6	345±12
					.776	18	93.5	360±7
	G 3	No potash, 1902 to 1906..			.776	18	95.9	331±3
					1.551	18	61.2	229±17
						18	50.8	279±12
						18	64.9	235±3
	F 8	Potash, 1901 to 1906.....				18	65.4	202±7
						18	64.7	218±8
						18	65.4	230±10
						18	60.1	228±6

¹ Computed from Wimmer's data (1906, pp. 15-37). Mean of two determinations.² Each pot received 0.840 gram N and 0.284 gram P₂O₅ in 1904, and 1.120 grams N and 0.284 gram P₂O₅ in 1905.³ Each pot received 1.400 grams N and 0.710 gram P₂O₅.

TABLE XXXVI.—*Effect of nitrogen on the water requirement of plants,¹ according to Wimmer.*

Crop and period.	Soil used.			Added N.	Soil moisture.	Mean dry matter.	Water requirement.
	Plat.	Previous fertilizer.	Soil per pot.				
Sugar beet: May 3 to Oct. 15, 1899.	Blendorf.....	Well manured.....	Grams. 8,058	Grams. 0.224	Per ct. 16	Grams. 38.2	515±55
			.336	.700	16	42.7	433±25
			1.820	.700	16	79.1	313±3
Ray-grass: May 1 to Nov. 1, 1903. ²	Waldau 33, 34, 35..	No potash since 1902; 0.284 gram P ₂ O ₅ per pot.	7,556	.280	12	34.1	230±20
				.700	12	43.8	254±10
				.280	15	35.4	372±32
				.700	15	52.2	232±10
				.280	18	44.0	329±38
				.700	18	53.7	322±10
	F 1, 3, 5, 7.....	No potash since 1902.	7,556	.280	12	33.9	323±12
				.700	12	39.6	285±8
				.280	15	44.9	302±12
				.700	15	51.7	259±4
				.280	18	48.3	319±19
				.700	18	57.7	293±7
Apr. 17 to Sept. 26, 1905.	F 3 ³	No potash since 1901.	7,768	.280	12	41.5	406±5
				1.120	12	72.2	296±6
	Waldau 87, 88, 89 ⁴ .	No potash since 1903.	8,042	.280	12	39.9	352±19
				1.120	12	45.9	337±42
	F 6 ⁵	Kainit since 1902..	7,808	.280	12	43.0	373±35
				1.120	12	75.8	276±6
	Juetrichau sand...	0.284 gram P ₂ O ₅ per pot.	8,000	.280	9	41.6	423±6
				1.120	9	50.7	323±33
	Buhlendorf sand...	do	8,000	.280	7	26.0	521±14
				1.120	7	60.7	336±31
Chicory: 1906.....	Buhlendorf sand ⁶ .	do	8,000	.280	12	48.9	287±2
				1.400	12	66.6	221±13
		0.710 gram P ₂ O ₅ per pot.	8,000	.280	12	55.8	256±13
				1.400	12	63.5	227±23
	Juetrichau sand ⁷ .	0.284 gram P ₂ O ₅ per pot.	8,000	.280	10	22.7	391±11
				1.400	10	10.8	676±17
		0.710 gram P ₂ O ₅ per pot.	8,000	.280	10	20.3	330±2
				1.400	10	10.7	606±76
Carrot: ² May 5 to Oct. 30, 1903.	Waldau 33, 34, 35..	No potash since 1902; 0.284 gram P ₂ O ₅ per pot.	7,556	.280	12	21.4	420±25
				.700	12	22.2	362±25
				.280	15	31.0	419±36
				.700	15	31.0	412±14
				.280	18	32.1	466±31
				.700	18	43.8	386±16
	F 1, 3, 5, 7.....	do	7,556	.280	12	19.6	458±17
				.700	12	17.3	470±46
				.280	15	31.9	352±10
				.700	15	28.5	396±14
				.280	18	32.1	442±23
				.700	18	44.2	309±15

¹ Computed from Wimmer's data (1903, pp. 89-114). Mean of two determinations.² Mean of three determinations.³ This soil contained in 1905 0.239 per cent K₂O and 0.039 per cent Na₂O.⁴ This soil contained in 1905 0.264 per cent K₂O and 0.038 per cent Na₂O.⁵ This soil contained in 1905 0.259 per cent K₂O and 0.079 per cent Na₂O.⁶ This soil contained 0.026 per cent K₂O and 0.032 per cent Na₂O.⁷ This soil contained 0.054 per cent K₂O and 0.051 per cent Na₂O.

WIDTSOE'S EXPERIMENTS.

Widtsøe (1909) conducted during 1904 and 1905 an experiment to test the effect of manure and mineral fertilizer on the water requirement of corn. The amounts of mineral fertilizers used (Table XXXVII) were calculated upon the weight of the upper 6 inches of soil and were added at the beginning of each year. All the fertilizers used were incorporated with the surface soil to a depth of 6 inches. Two open pots of College loam were used with each fertilizer treatment, one pot being planted to corn and the other kept barren to determine the evaporation from the soil. The pots were 24 inches in diameter and 30 inches high. The results show a reduction in the water requirement following the use of fertilizers, but the results for the two seasons are widely at variance.

Widtsøe later used three different types of soil in investigating the effect of fertilizers on the water requirement of corn. The results are also given in Table XXXVII. One soil consisted of an unproductive sand from a river wash, while the other two soils were productive. The experiments were carried on for but a single year, and only single pots were used for each fertilizer. The surface of the soil was not protected, and the evaporation was assumed to be the same as from bare check pots.

The soils in the various pots used had been treated differently in experiments previous to 1905 as regards culture, crops grown, methods of irrigation, and amount of water applied, but had been exposed without crop to atmospheric agencies from 1905 to 1908. "The amount of fertilizer applied in each case was nearly five times larger than in 1904 and 1905. As a result the depressing effect of the fertilizer is observed in a number of cases."

TABLE XXXVII.—*Effect of fertilizers on the water requirement of corn, according to Widtsøe (1909, pp. 49, 52).*

Year and soil.	Water requirement, using—				
	No fer-tilizer.	4 pounds manure.	0.1 per cent NaNO_3 .	0.01 per cent NaNO_3 .	0.1 per cent KCl.
1904, College loam	908	613	581	257	848
1905, College loam		315	151	237	431
Average		464	368	247	640

Year and soil.	Water requirement, using—							
	No fer-tilizer.	K	P	N	KN	KP	PN	KNP
1909:								
Sand	1,012	686	735	555	.....	671	178	460
College loam	357	308	391	471	450	333	339	303
Sanpete clay	306	292	375	385	280	383	.....	.....

KIESELBACH'S EXPERIMENTS.

Kiesselbach (1910) measured the water requirement of corn plants grown in river sand which was kept saturated with Schimpers's normal nutrient solution. Four concentrations, 0.6, 0.4, 0.2, and 0.1 per cent, were employed. Five pots, each holding about 15 kilograms and containing a single plant, were used for each concentration. The method followed is the same as that described on page 20. With the exception of the highest concentration, which reduced the growth of the plants, the results (Table XXXVIII) show a slight increase in the water requirement as the concentration of the solution is diminished.

TABLE XXXVIII.—*Influence of concentration of soil nutrient solution on the water requirement of corn, according to Kiesselbach (1910).*

Strength of solution.	Dry weight including roots.	Water requirement.
<i>Per cent.</i>	<i>Grams.</i>	
0.6	47.8	245 ± 5
.4	74.9	226 ± 6
.2	65.3	238 ± 4
.1	73.4	260 ± 4

LEATHER'S EXPERIMENTS.

Leather (1910, 1911) has investigated the use of nitrogen, potassium, and phosphorus as fertilizers in their relation to the water requirement of a number of crops in India. These experiments were conducted with four soils, which may be characterized as follows: The Pusa soil, where the Pusa Institute is situated, consists of Gangetic alluvium and contains a small proportion of clay. It is highly calcareous (30 to 40 per cent CaCO_3), low in organic matter, and very poor in available phosphate. Potash salts have no effect on the crop. The Akola soil is a typical "black cotton" soil, with a high clay content and from 1 to 3 per cent of calcium carbonate. The Shillong soil is highly ferruginous and contains much organic matter. The Palur soil is sandy in character.

The water requirements of crops grown in these soils, showing the effect of various fertilizers, are given in Table XL. Each determination refers to the mean value of the water requirement obtained from two pots, except in the case of the earlier measurements for wheat and corn, which represent the mean of the values given in Table XXXIX. The soil water content, except in the earlier determinations, was maintained as nearly as possible at 20 per cent of the saturation content. The writers have added the probable error of the mean in each case as a guide in making comparisons.¹

¹ The probable error, when only two determinations are available, has little value other than that of serving to show how closely the duplicate determinations agree. Usually in comparing mean values to determine whether a real difference exists, a difference equal to three times the square root of the sum of the squares of the two probable errors is considered the minimum significant difference. The probable error of the probable error of the mean of two determinations is one-half that of the probable error of the mean.

These determinations include the variation in water requirement arising from seasonal differences, kind and amount of soil used, and the kind of fertilizer employed. The magnitude of the probable errors shows that there were also in many cases other disturbing factors of a serious character which were not under control. Although the water requirement for a given crop varies widely according to season, soil, and fertilizer, the results show conclusively a marked reduction in the water requirement accompanying the use of phosphate as a fertilizer for these soils. Representing the water requirement of the unmanured soil in each case by 100, the mean value when nitrogen alone was used was 97; nitrogen and phosphorus, 75; nitrogen, potassium, and phosphorus, 73. These results indicate, therefore, the necessity of an adequate supply of plant food in order to secure the most economical use of a given water supply.

TABLE XXXIX.—*Influence of fertilizers on the water requirement of wheat and corn at Pusa, India,¹ according to Leather (1910).*

Crop and year.	Jar capacity.	Water in soil.	Water requirement, using—					
			No ferti- liser.	N	N + P	N + P + K	Mean.	Mean, omit- ting N + P + K.
Wheat (<i>Triticum sativum</i>):	Kilograms.	Per cent.						
1906-7.....	15	10	900	1,050	543	527	755	
		15	653	944	540	515	663	
		20	829	1,000	574	583	747	
	22	10	941	806	593	614	739	
		15	1,060	837	504	604	751	
		20	955	865	515		726	
Means for 1906-7.....			890 ± 37	917 ± 30	545 ± 10	569 ± 14		
1907-8.....	15	10	634	* 523	* 571		576	
		20	1,133	* 725	* 725		861	
	29	10	696	* 500	* 446		547	
		20	821	* 575	* 506		634	
	Means for 1907-8.....			821 ± 75	581 ± 35	562 ± 43		
	Corn (<i>Zea mays</i>) grown in Pusa soil: ^a							
1907.....	15	10	459	404	287	344		383
		15	368	377	323	322		356
		20	604	529	382	336		506
	21	10	500	645	309			485
		15	589		281			* 452
		20	381	527	295			401
	31	10	450	412	262			375
		15	421	505	286			404
		20	429	480	295			401
	Means for 1907.....			467 ± 19	485 ± 21	302 ± 7	334 ± 7	

¹ A single open pot was used for each treatment.

² The mean value 569 was used for the absent term of the N + P + K series in calculating this mean.

³ In these determinations rape cake was used, equivalent to 5 milligrams N per 100 grams of soil.

⁴ In these determinations superphosphate plus phosphoric acid in rape cake was used, equivalent to 10 milligrams soluble P_2O_5 per 100 grams soil.

⁵ $N = Ca(NO_3)_2 = 5$ milligrams N per 100 grams soil; $P =$ superphosphate = 10 milligrams soluble P_2O_5 per 100 grams soil.

⁶ The mean of the N ratios was used in place of the absent term in calculating this average value.

TABLE XL.—*Water requirement of crops at Pusa, India, as modified by soils and fertilizers, according to Leather (1910, 1911).*

Crop and year.	Soil.	Weight of soil.	Water requirement, using—			
			No fertiliz.	N	N+P	N+P+K
<i>Wheat (Triticum sativum):</i>						
1906-7.....	Pusa.....	Kilos. 15-22	890±37	917±30	545±10	569±14
1907-8.....	do.....	15-29	821±75	581±35	562±43	.....
1908-9.....	do.....	14	865±14	782±72	508±24	.....
1909-10.....	do.....	48	582±11	.....	495±2	.....
1909-10.....	Akola.....	41-45	842±6	.....	.....	440±16
1909-10.....	Shillong.....	43-45	526±31	.....	.....	580±10
<i>Corn (Zea mays):</i>						
1907.....	Pusa.....	15-31	467±19	485±25	302±7	334±7
1908.....	do.....	14	421±21	438±35	433±9	.....
1908.....	Akola.....	42-5	678±110	529±32	315±5	367±15
1908.....	do.....	12	447±8	468±71	355±9	340±8
1908.....	Shillong.....	32	466±46	521±16	287±8	306±6
1908.....	do.....	12	614±29	539±62	342±7	.....
1908.....	Palur.....	32	412±15	261±13	363±4	375±1
<i>Sarson (Brassica campestris):</i>						
1908-9.....	Pusa.....	14	737±15	818±59	625±16	.....
1909-10.....	do.....	48	481±8	.....	384±6	.....
1909-10.....	Akola.....	43	608±11	.....	.....	479±13
<i>Linseed (Linum usitatissimum):</i>						
1908-9.....	Pusa.....	14	1,063±120	1,198±83	1,000±36	.....
1909-10.....	do.....	48	1,094±150	.....	633±39	.....
1909-10.....	Akola.....	42-45	1,125±89	.....	.....	787±8
<i>Barley (Hordeum vulgare):</i>						
1908-9.....	Pusa.....	14	678±1	429±5	482±30	.....
1909-10.....	do.....	48	448±31	.....	455±3	.....
<i>Oats (Avena sativa):</i>						
1908-9.....	do.....	14	873±210	827±37	551±51	.....
1909-10.....	do.....	48	493±7	.....	388±11	.....
<i>Peas (Pisum sativum):</i>						
1908-9.....	do.....	14	836±120	785±36	531±65	.....
1909-10.....	do.....	48	811±3	.....	595±21	.....
<i>Gram (Cicer arietinum):</i>						
1908-9.....	do.....	14	1,427±79	1,166±120	976±130	.....
1909-10.....	do.....	48	1,216±160	.....	660±11	.....
<i>Juar (Andropogon sorghum):</i>						
1908.....	do.....	14	361±76	420±58	437±41	.....
<i>Rice (Oryza sativa):</i>						
1908.....	do.....	14	976±130	850±97	811±11	.....
<i>Murwa (Eleusine coracana):</i>						
1908.....	do.....	14	254±42	283±23	263±2	.....
<i>Kodo (Paspalum scrobiculatum):</i>						
1908.....	do.....	14	326±0	266±6	312±4	.....
<i>Rahar (Cajup indicum):</i>						
1908.....	do.....	14	1,109±82	1,245±100	640±31	630±21
<i>Guar (Cyamopsis psoraloides):</i>						
1908.....	do.....	14	1,062±15	1,060±140	596±5	.....
<i>Sugar cane (Saccharum officinarum):</i>						
1910.....	do.....	47	388±70	312±13	212±1	.....

VON SEELHORST'S LATER EXPERIMENTS.

Von Seelhorst (1910a) conducted experiments on the water requirement of rye in pots which had been previously manured for several years. This experiment was conducted in the large pots shown in figure 4 and described on page 68. The results are shown in Table XLV (p. 56). Referring to the water requirement of rye following rye, it will be seen that the lowest value was obtained by a light application of manure in the spring. The value obtained from a heavy application of manure in the fall was about 5 per cent higher, while the water requirement of the check pot, which had received no fertilizer, was about 19 per cent higher. The mean water requirement of the whole series receiving a heavy application of manure in the fall was also about 9 per cent higher than that of the series receiving a light application of manure in the spring.

MONTGOMERY AND KIESSELBACH'S EXPERIMENTS.

Montgomery and Kiesselbach (1912) measured the water requirements of corn grown in three types of soil, which they characterized as infertile, intermediate, and fertile. Each soil was used in its original condition and also with the addition of manure. Twenty-three cans were used in all, four being used for each treatment, with a single exception. The cans were 16 inches in diameter and 36 inches high. A single corn plant was grown in each can. The potometers were covered, as in their earlier experiments. Modeling clay was used to make a tight joint between the stalk of the corn and the oilcloth cover. A summary of the experiments is given in Table XLI.

The marked reduction in water requirement with the increase in soil fertility is definitely indicated. Another striking fact is the uniformity in the water requirement of corn obtained in all three soil types when manure was used. The ratios obtained in the three experiments in which manure was used differ by less than the probable error, either when based upon total dry matter or upon the dry weight of the ears.¹

TABLE XLI.—*Water requirement of corn as influenced by soil fertility, according to Montgomery and Kiesselbach (1912, pp. 10-11).*

Soil.	Average dry weight per plant.		Water requirement based on—			
			Total dry matter.		Dry ears.	
	No manure.	Manure.	No manure.	Manure.	No manure.	Manure.
	Grams.	Grams.				
Infertile.....	113	378	550 ± 16	350 ± 8	2, 136 ± 436	692 ± 45
Intermediate.....	184	414	479 ± 11	341 ± 4	1, 100 ± 59	679 ± 36
Fertile.....	270	473	392 ± 6	347 ± 6	799 ± 39	662 ± 18

PFEIFFER, BLANCK, AND FLÜGEL'S EXPERIMENTS.

Pfeiffer, Blanck, and Flügel (1912), experimenting with the effects of different amounts of nitrogen on the water requirement of plants, found that for the particular soil used the addition of nitrogen did not measurably lower the water requirement. The experiment is discussed in connection with the effect of soil-moisture content on the water requirement and the results are shown in Table XIII (p. 24).

CONCLUSIONS.

Almost without exception the experiments herein cited show a reduction in the water requirement accompanying the use of fertilizers. In highly productive soils this reduction amounts to only a

¹ The writers are indebted to Prof. Kiesselbach for an advance proof of this paper, and also for detailed information concerning earlier experiments, which has made the calculation of probable errors possible.

small percentage. In poor soils the water requirement may be reduced one-half or even two-thirds by the addition of fertilizers. Often the high water requirement is due to the deficiency of a single plant-food element. As the supply of such an element approaches exhaustion the rate of growth as measured by the assimilation of carbon dioxid is greatly reduced, but no corresponding change occurs in the transpiration. The result is inevitably a high water requirement.

As a whole, these experiments show clearly that transpiration is not a measure of growth, even under the same atmospheric conditions, and that the water requirement is profoundly affected by the plant food available in the soil.

WATER CULTURES.

WOODWARD'S EXPERIMENTS.

The earliest experiments conducted for the purpose of determining the water requirement of plants, so far as the writers are aware, were made by Woodward in 1699 with water cultures. Plants of known green weight were transplanted to vials. A cork stopper prevented loss of water except through the plant, and an accurate record was kept of the water consumed. The difference between the initial and final green weight was taken to represent the amount of growth.

Woodward's results, expressed in terms of green weight, are given in Table XLII. Although his experiments were made on water cultures 200 years ago, the results obtained are of fundamental importance. He found the water requirement of plants grown in spring water and in rain water to be higher than when grown in waters containing more soluble matter. Moreover, when impure water was distilled the water requirement of plants was found to be higher when grown in the distillate than when grown in the residue. This leads at once to the conclusion that the water requirement of plants is, within limits, dependent on the amount of plant food available.

TABLE XLII.—*Effect of pure and impure water on the water requirement of plants, according to Woodward (1699, pp. 200-206).*

Plant, water used, etc.	Year.	Increase in green weight.	Water transpired.	Water re- quirement, green weight.
Spear-mint:		<i>Grams.</i>	<i>Kilograms.</i>	
Spring water.....	1691	0.97	0.165	170
Rain water.....	1691	1.134	.195	172
Thames water.....	1691	1.68	.161	95
Hyde Park conduit water.....	1692	8.20	.92	111
Hyde Park conduit water and garden earth.....	1692	9.00	.851	95
Hyde Park conduit water and garden mold.....	1692	10.88	.095	64
Hyde Park conduit water, distilled.....	1692	18.4	.960	53
Residue.....	1692	2.66	.572	215
	1692	6.09	.281	46
Solanum:				
Spring water.....	1691	3.695	.241	65
Lathyrus:				
Spring water.....	1691	.227	.162	715

SORAUER'S EXPERIMENTS.

Sorauer (1883) used water cultures in most of his water-requirement experiments. His results, which deal with the effect of different amounts of nutrient solution on the water requirement of rye, barley, wheat, and oats, are given in Table XLIII. The experiments were of 53 days' duration, and the water requirement was found to decrease as the concentration of the nutrient solution increased.

TABLE XLIII.—*Effect of the concentration of the nutrient solution on the water requirement of plants,¹ according to Sorauer (1883, pp. 90-91).*

Crop.	Concentration of the nutrient solution.									
	0.05 per cent.		0.25 per cent.		0.5 per cent.		1 per cent.		0.25 per cent nutrient+0.5 per cent calcium nitrate.	
	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.
Rye.....	4	495±22	4	331±22	3	287±21	4	197±20	5	235±25
Barley.....	4	547±39	3	432±14	4	321±11	4	289±8		
Wheat.....	4	768±40	4	647±19	4	469±18				
Oats.....	4	630±24	4	569±20			3	323±32		
Mean.....		610		495						
Mean for rye and barley.....		521		382		294		243		

¹ The total dry matter produced was seldom as great as 0.5 gram per pot.

HEINRICH'S EXPERIMENTS.

Heinrich (1894) has determined the water requirements of oat plants when grown in nutrient solutions of different concentration. The nutrient solution had the following composition: 4 H_2KPO_4 + CaCl_2 + 5 $\text{Ca}(\text{NO}_3)_2$ + 2 MgSO_4 + 2 Fe. Five concentrations were used, 3 grams, 1 gram, 0.5 gram, 0.25 gram, and 0.1 gram per liter. The iron was supplied in the form of freshly precipitated suspended iron phosphate. Ten jars, each containing 3 liters of solution, were used for each of the five concentrations. Three plants were grown in each jar. An equal number of jars without plants was used to determine the evaporation taking place directly from the culture solution. The plants were grown for four months, or until ripe. The transpiration was determined by weekly weighings. The plants in the 0.3 per cent solution consumed about three-fourths of the initial water supply. The evaporation in this case was only about 2.5 per cent of the transpiration. The results are given in Table XLIV. With the exception of the weakest solution, the water requirement decreased as the concentration of the solution increased.

TABLE XLIV.—*Water requirement of oat plants grown in culture solutions of different concentrations, according to Heinrich (1894, p. 173).*

Concentration of culture solution.	Dry matter.	Grain.	Water transpired.	Water requirement based on—	
				Grain.	Dry matter.
	<i>Grams.</i>	<i>Grams.</i>	<i>Kilos.</i>		
3 grams per liter.....	134.3	5.42	69.2	12,800	515
1 gram per liter.....	74.4	2.71	40.9	15,100	550
0.5 gram per liter.....	41.5	.59	28.4	48,200	684
0.25 gram per liter.....	27.8	1.07	19.1	17,900	688
0.1 gram per liter.....	17.6	1.41	11.3	8,020	642

CONCLUSION.

The water requirement of plants grown in water cultures is increased if the solution is lacking in a sufficient amount of plant food.

EFFECT OF A PREVIOUS CROP ON THE WATER REQUIREMENT.

VON SEELHORST'S EXPERIMENTS.

The effect of a previous crop on the water requirement of rye is shown in a series of determinations made by Von Seelhorst (1910a). These determinations were made in the large pots shown in figure 4 (p. 68). The results of the determinations are given in Table XLV. The experiments were conducted with two series of pots, one series having received a light application of manure each spring from 1904 to 1907 and the other a heavy application of manure each fall during the same period. A crop was grown in each pot from 1905 to 1908. In the fall of 1908 all pots were planted to rye and the crop harvested in 1909.

TABLE XLV.—*Effect of a previous crop on the water requirement of rye, according to Von Seelhorst (1910a, p. 91).¹*

Application of manure, 1904 to 1907.	Crops, 1906 to 1908.	Rye, 1908-9.		
		Number of pots.	Yield.	Water requirement.
			<i>Grams.</i>	
Light, in spring.....	Potatoes.....	3	426	743 ± 23
	Rye.....	2	393	759 ± 4
	Barley.....	1	526	589
Mean.....				697
Heavy, in fall.....	Potatoes.....	3	421	748 ± 18
	Rye.....	2	374	801 ± 33
	Barley.....	1	483	666
Mean.....				738
No manure added (check).....	Rye.....	1	339	900

¹ The water requirement includes evaporation. The soil was sandy. The results were compiled from Von Seelhorst's data. In the late summer and fall of 1906 each pot, with the exception of the unmanured set, produced a crop of lupine.

The results of this experiment show that when rye follows potatoes the yield and water requirement are not measurably different from that obtained when rye follows rye. When rye follows barley, however, the yield is increased and the water requirement is reduced, compared with rye following rye. The lower water requirement would naturally result from the increased supply of plant food in the barley pots, as indicated by the higher yields.

EFFECT OF SOIL TEMPERATURE ON THE WATER REQUIREMENT.

KING'S EXPERIMENTS.

King (1895) compared the water requirement of potatoes when grown in pots above ground with similar determinations made in pots buried in the soil. The pots above ground were protected from the direct rays of the sun by a board screen placed on the south side. Galvanized-iron pots 18 inches in diameter and 24 inches high were used. The plants were covered at night and during rains with a tent of heavy duck. It was found that the water requirement was apparently less when the pots were placed in the ground, but the difference observed can not be considered conclusive, since it is less than three times the probable error (Table XLVI). No data are given regarding the temperature fluctuations in the two series of pots. It seems probable that the more exposed position of the plants grown in the pots above ground would also affect the results.

TABLE XLVI.—*Effect of soil temperature on the water requirement of potatoes,¹ according to King (1895, p. 243).*

Treatment of pots.	Dry matter.	Water.	Water requirement based on dry matter.
	<i>Grams.</i>	<i>Kilograms.</i>	
Above ground.....	227.7	107.4	472
	163.0	97.4	597
	246.1	112.9	458
			509 ± 35
Sunk in potato field.....	232.5	100.1	430
	238.2	99.0	415
			423 ± 6

¹ Alexander's Prolific.

² King gives 497, which is evidently an error.

LEATHER'S EXPERIMENTS.

The pot-culture method of measuring the water requirement of plants subjects the soil to greater temperature fluctuations than occur under field conditions, owing to the exposure of the pots to the direct rays of the sun. To determine the effect of this exposure, Leather (1910) thermally insulated jars in which maize and wheat were growing by surrounding them with from 5 to 7 inches of sawdust throughout the period of growth. These were compared with jars fully

exposed to the sun but otherwise similar in every respect. The results, which are given in Table XLVII, show that the effect of the exposure of the pots to the sun is within the limits of other experimental errors.

TABLE XLVII.—*Water requirement of plants as influenced by the exposure of culture pots to the sun, according to Leather (1910, p. 142).*

Crop.	Fertilizer.	Water requirement.	
		Pots protected from sun.	Pots exposed to sun.
Corn.....	Nitrate and phosphate.....	428	382
	No fertilizer.....	630	606
Wheat.....	Rape cake and phosphate.....	832	725
	No fertilizer.....	1,014	1,133
Mean.....		726	712

CONCLUSIONS.

From the data at hand no conclusion can be drawn concerning the effect of soil temperature on the water requirement. Leather's data indicate that the greater fluctuation in soil temperature accompanying the exposure of the pots to the sun does not materially affect the water requirement.

EFFECT OF CLIMATIC FACTORS ON THE WATER REQUIREMENT.

EFFECT OF DIFFERENT ATMOSPHERIC CONDITIONS ON THE WATER REQUIREMENT.

That atmospheric factors profoundly influence the water requirement is evident from the data of numerous investigators. The effects of temperature, light, humidity, etc., will be discussed later. Here we wish to present the results which can be considered only as due to a difference in atmospheric conditions as a whole.

FITTBÖGEN'S EXPERIMENTS.

Fittbøgen (1874) published the results of measurements of the water requirement made in a plant house and in the open at the south side of the plant house. The culture method was the same as that used in 1873 (p. 12). The soil-moisture content was 50 to 60 per cent of the moisture-holding capacity. The difference in the water requirement (Table XLVIII) of the plants grown inside and outside was 15 ± 6 , which is without significance when the probable error is considered. The plants grown in the plant house were probably warmer, but were at the same time slightly shaded. On the other hand, the outside set received somewhat more solar radiation and was exposed to freer wind movement. It is impossible from data of this kind to draw conclusions as to the specific effect of temperature, light, or humidity upon the water requirement, since none of these factors were comparable for the two series.

TABLE XLVIII.—*Effect of different atmospheric conditions on the water requirement of oats, according to Fittbogen.*

Position.	Number of determinations.	Dry matter.	Grain.	Water requirement ¹ based on—	
				Grain.	Dry matter.
Inside of plant house.....	4	Grams. 13.7	Grams. 7.01	777±10	398±6
Outside of plant house, on south side.....	4	12.7	6.46	810±3	413±1

¹ Calculated from Fittbogen's data (1874, p. 145).

HELLRIEGEL'S EXPERIMENTS.

Hellriegel (1883) determined the effect of seasonal differences upon the water requirement by a series of measurements. The results are given in Table XLIX. Red clover was used in this experiment, croppings being made at four different times during a period of two years and the water requirement of each crop determined. It will be seen from this table that the water requirement was much higher for the crops harvested in September and January than for the crops harvested in June and July, owing to variation in the climatic conditions with different periods of the year. Hellriegel also conducted a series of experiments which show the effect of different years on the water requirement. (Table LXVII, p. 75.) The water requirement of barley in 1868 was almost 40 per cent higher than in 1870. Similar results were obtained during different seasons with other crops.

TABLE XLIX.—*Effect of the period of growth on the water requirement of red clover, according to Hellriegel (1883, p. 634).*

Pot used.		Date of cropping.							
Height.	No.	July 17, 1872.		Sept. 14, 1872.		Jan. 8, 1873.		June 5, 1873.	
		Dry matter.	Water requirement.	Dry matter.	Water requirement.	Dry matter.	Water requirement.	Dry matter.	Water requirement.
15 centimeters.....	314 315	Grams. 12.8 15.0	362 311	Grams. 12.8 8.4	435 671	Grams. 0.5 1.2	1,588 1,645	Grams. 26.6 18.2	292 467
Mean.....			337±22		553±100		1,617±25		380±76
34 centimeters.....	346 347	26.2 14.3	349 401	Not cropped. 14.3	652	23.6 2.5	763 854	69.8 80.8	264 302
Mean.....			375±22				809±39		283±16
65 centimeters.....	348 349	30.0 21.0	293 417	25.8 21.2	439 546	10.2 5.2	451 649	111.5 98.4	256 285
Mean.....			355±53		493±46		545±79		271±13
96 centimeters.....	350 351	26.2 25.0	357 410	Not cropped. 17.4	677	52.5 11.0	680 563	168.2 157.0	243 263
Mean.....			384±23				622±50		253±8

KING'S EXPERIMENTS.

King (1905) measured the water requirement of corn in several different places in the United States. (Table XV, p. 27.) Different types of soil were employed, and the differences in the water requirement can not therefore be entirely attributed to varying climatic conditions.

VON SEELHORST'S EXPERIMENTS.

In his experiments with pasture and grassland plants Von Seelhorst (1910) found that the water requirement varied greatly at different periods of the year. His results (Table LIX, p. 69) show that the water requirement of the pasture crop was the lowest from April 1 to May 16; from May 16 to June 20 it was 58 per cent higher; from June 20 to July 29, 350 per cent higher; and from July 29 to September 16, 110 per cent higher. The results of the following year show the water requirement of pasture plants to be over 90 per cent higher for the period June 4 to June 28 than for the period April 6 to June 4. Similar results were obtained with the grassland pots.

BRIGGS AND SHANTZ'S EXPERIMENTS.

The writers in their work at Akron, Colo., have found that the water requirement of alfalfa (Table L) was the lowest for the period from September 18 to October 22. From May 13 to July 19 it was 94 per cent higher, and from July 19 to September 18, 160 per cent higher. With sweet clover the water requirement for the period from July 19 to September 21 was 17 per cent higher than for the period from May 13 to July 19.

TABLE L.—*Effect of the period of growth on the water requirement of crops, according to Briggs and Shantz (1913, p. 31.)*

Crop.	Period of growth.	Water requirement.	Crop.	Period of growth.	Water requirement.
Alfalfa.....	May 13 to July 19.....	1,008±26	Sweet clover....	May 13 to July 19.....	675±5
	July 19 to Sept. 18.....	1,354±22		July 19 to Sept. 21.....	793±12
	Sept. 18 to Oct. 22.....	520±9			

A comparison of the writers' measurements of the water requirement of wheat and sorghum grown in northeastern Colorado and in the Panhandle of Texas during the seasons of 1910 and 1911 is given in Table LI. The results show a higher water requirement for the crops grown in Texas, but the difference is relatively much greater for wheat than for sorghum, indicating that at least one of the crops is better adapted to one region than to the other.

TABLE LI.—*Comparison of evaporation and water requirement in Colorado and Texas, according to Briggs and Shantz (1913, p. 45).*

Years and stations.	Wheat.					Sorghum.				
	Period of growth.	Evapora- tion.		Water re- quire- ment.		Period of growth.	Evapora- tion.		Water re- quire- ment.	
		Ac- tual.	Rel- ative.	Ac- tual.	Rel- ative.		Ac- tual.	Rel- ative.	Ac- tual.	Rel- ative.
1910.										
Akron, Colo...	Apr. 18 to Aug. 2..	27.7	100	664	100	May 25 to Sept. 28.	33.0	100	356	100
Amarillo, Tex.	Apr. 5 to July 19..	34.0	122	853	128	May 10 to Aug. 28.	37.7	114	359	101
1911.										
Akron, Colo...	May 13 to Aug. 2..	24.8	100	468	100	May 12 to Sept. 4..	35.0	100	298	100
Dalhart, Tex..	Apr. 25 to July 18.	28.5	115	673	143	May 14 to Sept. 12.	41.9	120	313	105

CONCLUSIONS.

The data here presented show clearly that the water requirement is profoundly affected by atmospheric conditions. Measurements of the water requirement conducted during different periods of the year show great differences. Experiments conducted at different places during the same period, using the same variety, give different values for the water requirement, owing to differences in the climatic conditions. Even though the methods and soil conditions are the same for two different years, profound differences are often recorded in the water requirement.

EFFECT OF AIR TEMPERATURE ON THE WATER REQUIREMENT.

The effect of temperature on the water requirement of plants does not appear ever to have been investigated under control conditions. Seasonal changes in temperature are accompanied by changes in the saturation deficit, so that the differences observed in the water requirement of plants resulting from the march of the seasons can not be attributed to temperature alone. The investigations which have so far been made on this subject have only a qualitative bearing. See Fittbogen (1874), Table XLVIII (p. 59); Hellriegel (1883), Table XLIX (p. 59); King (1905), Table XV (p. 27); Von Seelhorst (1910), Table LIX (p. 69); and Briggs and Shantz (1913), Table L (p. 60) and Table LI (p. 61).

EFFECT OF SHADE ON THE WATER REQUIREMENT.

It is well recognized that sunlight is an important factor in increasing transpiration. It is also known that in ordinary sunlight more solar energy is received by the plants than is necessary for photosynthesis. It seems evident, therefore, that an increase in solar intensity would cause an increase in the rate of loss of water from the plant without changing the rate of carbon fixation. Under such con-

ditions increased sunlight would, of course, increase the water requirement.

On the other hand, the use of shade might be expected to lower the water requirement, so long as photosynthesis is not interfered with.

If the shading is carried so far as to prevent carbon fixation at the normal rate, then the water requirement would again increase.

SORAUER'S EXPERIMENTS.

Sorauer (1880, p. 463) determined the water requirement of bean plants in the dark and in the light. The plants were grown for 20 days under bell jars, four pots being used in each experiment. The water requirement of plants grown in the dark was 21 ± 3 , and of plants in the light, 47 ± 1 . This experiment does not really afford any evidence with respect to the effect of light upon the water requirement, since no elaboration of carbohydrates is possible in the dark. Furthermore, no correction was made for the initial weight of the seedling plants, and the apparently low water requirement of plants grown in the dark is due to this. This experiment illustrates the possibility of securing misleading results from the use of seedlings in water-requirement measurements.

HELLRIEGEL'S EXPERIMENTS.

The experiments of Hellriegel (1883) are more conclusive. The results are given in Table LII. The water requirement was found to be lowest when the plants were grown in full light, and increased with increasing shade. The actual light reduction resulting from the use of the different screens is not stated. The "medium" screen increased the water requirement of the barley approximately 50 per cent and of the peas about 75 per cent.

TABLE LII.—*Effect of different light intensities on the water requirement of barley and peas,¹ according to Hellriegel (1883, p. 633).*

Plant.	Size of pot.	Full light.		Shade.					
		Dry matter.	Water requirement.	Wide screen.		Medium screen.		Close screen.	
				Dry matter.	Water requirement.	Dry matter.	Water requirement.	Dry matter.	Water requirement.
Barley.....	65 by 67 centimeters...	Grams. 57.3	360	Grams. 15.3	498	Grams. 10.8	510	Grams. 7.7	609
	34 by 35 centimeters...	28.0	338	12.2	468	11.8	528	6.5	542
	Mean.....		349 ± 9		483 ± 13		519 ± 8		576 ± 29
Peas.....	34 by 35 centimeters...	38.4	343						
		37.1	364			11.4	624		
			354 ± 9						

¹ Garden soil was used. The amount of soil did not affect the water requirement. Evaporation was prevented by waxed-board covers. Each given determination of water requirement is the mean value of two measurements, except that the one for shaded pea is a single measurement.

PFEIFFER, BLANCK, AND FLÜGEL'S EXPERIMENTS.

Pfeiffer, Blanck, and Flügel (1912) obtained a slight increase in the water requirement of oats, due to shade. Unfortunately, however, no idea is given of the light reduction resulting from the use of the shade. Their results are given in Table XIII (p. 24). The difference in the water requirement of the shaded series and the series in full light was 20 ± 3 , which corresponds to an increase of about 5 per cent due to shading.

CONCLUSIONS.

The intensity of the sunlight or the extent to which it was reduced by the various shades used is not stated in any of the above investigations, so that it is not possible to draw specific conclusions from the data here presented. All of these data, however, indicate that shading produces an increase in the water requirement. It seems probable that in these experiments the shade was so dense as to reduce photosynthesis. This would in turn decrease the rate of growth and so increase the water requirement.

EFFECT OF AIR HUMIDITY ON THE WATER REQUIREMENT.

SORAUER'S EXPERIMENTS.

Sorauer (1880) investigated the effect of humidity on the water requirement by growing a number of woody plants in moist air and in dry air. (Table LIII.) The water requirement in moist air averaged about 80 per cent of the water requirement in dry air.

TABLE LIII.—*Effect of dry and moist air on the water requirement of woody plants, according to Sorauer (1880, p. 435).*

Plants.	Duration.	Moist air.		Dry air.	
		Number of determinations.	Water requirement.	Number of determinations.	Water requirement.
	<i>Days.</i>				
<i>Pyrus communis</i>	39	1	284	1	353
<i>Pyrus malus</i>	39	3	146 ± 3	2	233 ± 27
<i>Vitis vinifera</i>	39	2	113 ± 8	2	220 ± 47
<i>Alnus glandulosa</i>	39	1	497	1	467
<i>Robinia pseudoacacia</i>	39	1	331	1	441
Mean.....			274		348

HEINRICH'S EXPERIMENTS.

Heinrich (1894) grew oats in damp air and in air dried by calcium chlorid. (Table LIV.) The plants were grown in glass pots, only one pot being used in each experiment. The relative humidity of the air is not given in either experiment. The results are very striking, the water requirement of the plants grown in dry air being over five times that of the plants grown in moist air.

TABLE LIV.—*Effect of dry and moist air on the water requirement of oats,¹ according to Heinrich (1894, pp. 170–171).*

Treatment.	Dry matter.	Water.	Water requirement on basis of dry matter.
	Grams.	Kilograms.	
Moist air.....	5.444	0.6549	* 120
Dry air.....	8.906	5.5567	618

¹ Duration of experiment, May 14 to July 29; 3 plants per pot.² Heinrich gives 102, which is evidently an error.

MONTGOMERY AND KIESSSELBACH'S EXPERIMENTS.

The most conclusive experiments on this subject are those of Montgomery and Kiesselbach (1912) with corn. Two greenhouses were used, one of which was ventilated and the other kept as humid as possible by wetting the floors and by using atomizers on the water system. The experiments were conducted in June and July. Apparently 4 large, covered pots, each containing 2 corn plants, were used in each house. Self-registering thermometers and hygrometers were used to record the temperature and humidity in each house and the evaporation from a free water surface (36 square inches) was also measured.

Montgomery and Kiesselbach's summary of the conditions in the two houses and the resulting water requirement is given in Table LV.

TABLE LV.—*Relation of humidity and other factors to the water requirement of corn, according to Montgomery and Kiesselbach (1912, p. 4).*

	Dry greenhouse.	Humid greenhouse.	Ratio, humid to dry.
Mean temperature:			
12 hours of night.....° F..	80	75	.....
12 hours of day.....° F..	91	88	.....
Mean relative humidity:			
12 hours of night.....per cent..	48	72	.....
12 hours of day.....do.....	37	58	.....
Total weight of 8 plants.....grams..	670.36	861.77	.....
Average leaf area per plant.....square inches..	1,079	1,070	.....
Total water used.....kilograms..	227.785	184.230	.....
Water requirement:			
Based on dry weight.....grams..	340	191	1.56
Based on square inches of leaf area.....do.....	27.3	19.2	1.70
Water evaporated from 36 square inches of free-water surface.....do.....	3,891	2,187	1.56

Table LV shows that the corn grown in the dry house had a water requirement 56 per cent higher than that in the humid house. It is of special interest to note that the evaporation from a free water surface in the dry house exceeded that in the humid house by the same amount, 56 per cent.

Another point of interest in connection with the above data which was not brought out by Montgomery and Kiesselbach arises

from the consideration of the relative humidity of the two houses. Other things being equal, the rate of evaporation would be proportional to the saturation deficit. This can, furthermore, be limited to the saturation deficit during the day, since the transpiration at night is so small that it can be disregarded.

The pressure of aqueous vapor in saturated air at the mean day temperatures of the dry and humid houses is 31.67 and 31.11 millimeters, respectively. The corresponding saturation deficits expressed in terms of vapor pressure would then be

$$31.67 \times (1.00 - 0.37) = 19.95 \text{ millimeters,}$$

$$\text{and } 31.11 \times (1.00 - 0.58) = 13.05 \text{ millimeters.}$$

The ratio of these saturation deficits is 1.53, as compared with 1.56 obtained experimentally as the ratio of the water requirements. The linear relationship which is thus indicated between the saturation deficit and the water requirement must, of course, be considered only as tentative until its validity shall have been determined through further experiments. It affords, however, a possible method of determining indirectly from the mean relative humidity the relative water requirement of crops in different sections of the country, provided the temperature and the other climatic factors are equally favorable for growth.

CONCLUSIONS.

All of the investigations that have been made relative to the effect of humidity on the water requirement of plants show conclusively that the water requirement is greater in dry than in moist air.

Montgomery and Kiesselbach have found that the water requirement of corn is proportional to the evaporation from a small free water surface. From their data the writers have shown that the water requirement is also approximately proportional to the saturation deficit.

EFFECT OF THE CARBON-DIOXID CONTENT OF THE AIR ON THE WATER REQUIREMENT.

SORAUER'S EXPERIMENTS.

Sorauer (1880) measured the effect of the carbon-dioxid content of the atmosphere upon the water requirement (Table LVI). Rape was grown in free air and also under two bell jars. In one of the bell jars a solution of potassium hydrate was kept to reduce the carbon dioxid of the air. The results indicate that the water requirement is greatly increased by reducing the carbon-dioxid content of the atmosphere.

TABLE LVI.—*Effect of insufficient carbon dioxide in the air on the water requirement of rape, according to Sorauer (1880, p. 467).*

Duration.	In free air.		Under bell jar.		Under bell jar, with potassium hydrate.	
	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.
<i>Days.</i> 20	4	282±11	3	243±5	2	355±5

CONCLUSIONS.

The effect of the carbon-dioxid content of the atmosphere upon the water requirement appears to have been investigated only by Sorauer. He found the water requirement to increase when the carbon-dioxid content was diminished. This is in accord with what is now known regarding the rôle of carbon dioxide in photosynthesis.

EFFECT OF PARASITES ON THE WATER REQUIREMENT.

WIMMER'S EXPERIMENTS.

Wimmer (1908) reported a series of experiments to show the effect of nematode-infested soil on the water requirement of sugar beets and celery. The results (Table LVII) show without exception an increase in the water requirement due to the action of the parasitic worms. This is probably due to the fact that infested plants grow much more slowly than those not infested, as is indicated by the weight of dry matter produced in each case.

TABLE LVII.—*Effect of nematodes¹ on the water requirement of sugar beets and celery, according to Wimmer.*

Crop and plot.	Weight of soil per pot.	Nematodes.	Fertilizer per pot.			Soil-moisture content.	Mean of dry matter.	Water requirement.
			K ₂ O	N	P ₂ O ₅			
Sugar beets:	<i>Grams.</i>		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	
A7n.....	8, 106	(Dead.....	.....	0.224	0.355	16	47.8	419±4
		(Alive.....	.....	.224	.355	16	19.1	933±118
	8, 106	(Dead.....	.....	1.820	.355	16	75.9	336±11
		(Alive.....	.....	1.820	.355	16	36.8	567±85
	8, 106	(Dead.....	.....	.700	.355	12	45.4	265±14
		(Alive.....	.....	.700	.355	12	34.4	474±26
A8n.....	8, 202	(Dead.....	0.705	.....	.355	16	21.9	710±41
		(Alive.....	.705	.....	.355	16	6.6	2,063±57
Celery:								
A7n.....	8, 106	(Dead.....	.705	.224	.335	14 to 15	52.2	299±49
		(Alive.....	.705	.224	.335	14 to 15	35.5	368±15 ²
A8n.....	8, 202	(Dead.....	.705	.....	.335	14 to 18	40.5	422±20 ³
		(Alive.....	.705	.....	.335	14 to 18	23.7	521±4

¹ The nematodes were killed by carbon-bisulphid treatment. Computed from Wimmer's data (1906, pp. 142-143, 154-155). A7n is the mean of two determinations, A8n the mean of three, except as noted.

² Mean of four determinations.

³ Mean of two determinations.

OTHER FACTORS INFLUENCING THE WATER REQUIREMENT.

THE EFFECT OF RELATIVE LEAF AREA ON THE WATER REQUIREMENT.

MONTGOMERY'S EXPERIMENTS.

Montgomery (1911) has investigated the influence of the leaf area of corn on its water requirement, using for this purpose selected strains having a high leaf area and a low leaf area, respectively. The plants were grown in large potometers of two sizes, one containing 1,000 pounds and the other 350 pounds of soil. The larger potometers contained two plants each, the smaller ones a single plant. The results of the experiments, which cover a period of three years, are given in Table LVIII, and show that, with an average difference in relative leafiness of 14 per cent, the more leafy type had a water requirement 7 per cent higher than the less leafy strain. The leafy plants required 16 per cent more water to produce an equal weight of ear.

TABLE LVIII.—*Effect of relative leaf area on the water requirement of corn, according to Montgomery (1911, p. 150).*

Year.	Ratio of leaf area to dry weight.		Ratio of high to low.	Water requirement.		Ratio of high to low.
	Low leaf area.	High leaf area.		Low leaf.	High leaf.	
1907.....	2.31	2.65	1.14	220	242	1.10
1909.....	2.33	2.73	1.17	263	287	1.09
1910.....	2.10	2.36	1.12	236	240	1.02
Mean.....			1.14±.01			1.07±.02

The transpiration per unit area of leaf was higher in the less leafy types, the ratio of low to high leaf area for the three years being 1.04, 1.07, 1.10. But some transpiration takes place also from the stalk, which would be relatively greater in the type with low leaf area, and the effect of this would be to make the transpiration of the low leaf-area strain per unit area appear higher than it really is. This effect is not sufficient, however, to account for the differences found between high leaf-area and low leaf-area types. From a computation made by the writers it appears that, in order to account for the observed differences in transpiration per unit area of leaf, the stalk would have to possess an area which is the equivalent as regards transpiration of 20 to 40 per cent of the total leaf area.

Montgomery's results indicate that the transpiration loss of corn in proportion to the growth made is decreased by a decreased leaf area. It is possible, however, that the narrow-leaved type developed through selection possessed also a varietal efficiency in the use of

water independent of its leaf area. Further experimentation, using strains of other plants with high and low leaf areas, is desirable in this connection.

EFFECT OF FREQUENT CUTTING ON THE WATER REQUIREMENT.

VON SEELHORST'S EXPERIMENTS.

Von Seelhorst (1910) conducted an experiment to determine the water requirement of grassland and pasture. The pots used by Von Seelhorst (1902, p. 276) had a surface 1 square meter in area, a depth of 1.3 meters, and were mounted upon trucks in a trench running east and west, which was provided with cement walls and floor

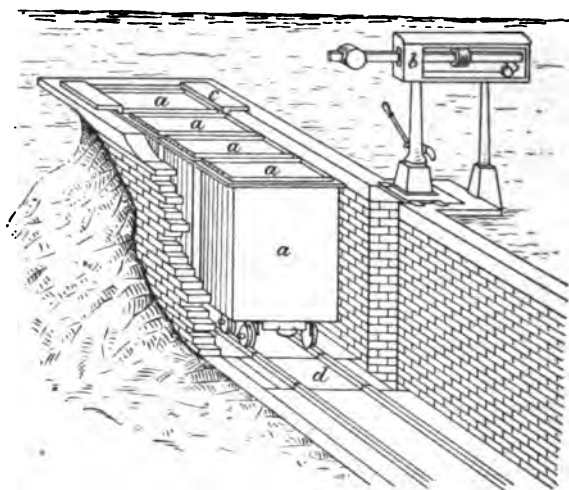


FIG. 4.—Apparatus used by Von Seelhorst (1902) in his later measurements of the water requirement of plants.

(fig. 4). The bottom of the pot (*a*) was so constructed as to permit free drainage. The scales (*b*) for weighing the trucks were built in as a part of the trench (*d*). The rainfall was determined from the rain-gauge measurements or directly by weighing, and the drainage water was also collected. No correction was made for evaporation. The pots which represented pasture were cropped more often than those which represented grassland. This was apparently the only difference in treatment. Ordinary grassland and pasture grasses were grown. The results of two years' work are shown in Table LIX, from which it will be seen that the water requirement was higher under pasture-land conditions than under grassland conditions. From these results, one would conclude that the frequent and continued cropping as the result of pasturing increases the water requirement

per unit of dry matter produced, and that grassland can produce dry matter more economically when allowed to continue its growth uncropped for a longer period.

TABLE LIX.—*Relative water requirement of pasture and grassland, according to Von Seelhorst (1910, pp. 84-87).¹*

Period of growth.	Pasture.		Grassland.	
	Dry matter.	Water requirement.	Dry matter.	Water requirement.
1908.	<i>Grams.</i>		<i>Grams.</i>	
Apr. 1 to May 16.....	150.6	248	512.5	370
Apr. 1 to June 12.....	156.0	715	263.7	733
May 16 to June 20.....	100.5	1,130	206.3	513
June 13 to July 29.....	135.0	546		
June 20 to July 29.....				
July 29 to Sept. 16.....				
Whole period, Apr. 1 to Sept. 16.....	542.1	620	972.5	495
1909.				
Apr. 6 to June 4.....	325.1	429	584	451
Apr. 6 to June 23.....	56.0	845		
June 4 to June 23.....				
Whole period, Apr. 6 to June 23.....	381.1	490	584	451

¹ Determinations were made in large pots, shown in figure 4 and described by Von Seelhorst (1908). Ordinary grassland and pasture plants were used. The experiment was continued until Sept. 27, 1909, but no comparable data are given after June 23, 1909.

EFFECT OF DEFOLIATION ON THE WATER REQUIREMENT.

SORAUER'S EXPERIMENTS.

Sorauer (1880) determined the effect of defoliation upon the water requirement of a grapevine grown in distilled water. The experiment was continued from July 14 to September 14. The results (Table LXIX) indicate that the removal of the leaves at the beginning of the experiment increased the water requirement over 50 per cent.

TABLE LX.—*Effect of defoliation on the water requirement of a grapevine, according to Sorauer (1880, p. 461).*

Plant.	In leaf.		Defoliated at start.	
	Number of determinations.	Water requirement.	Number of determinations.	Water requirement.
<i>Vitis vinifera</i> (Jaques).....	2	122±13	2	186±8

EFFECT OF THE AMOUNT OF GROWTH OR NUMBER OF PLANTS PER UNIT OF SOIL MASS ON THE WATER REQUIREMENT.¹

VON SEELHORST AND BÜNGER'S EXPERIMENTS.

Von Seelhorst and Bünger (1907) measured the water requirement of summer wheat when five plants were grown in each pot and when single plants were used. The experiments were carried out in pots containing 12 kilograms of soil. The results are given in Table XXXII (p. 44). In 14 out of 15 trials a higher water requirement was obtained when five plants were grown in a pot than when single plants were used. The increase in the water requirement was, however, small, averaging about 15 per cent for the low water-content series, and about 4 per cent for the high water-content series. It will be noted that the amount of dry matter produced varied greatly according to the treatment, and that in every case a single plant produced more than one-half as much dry matter as five plants taken together. As already suggested (p. 44), this indicates a deficiency of plant food in the small pots containing the five plants.

EFFECT OF THE AGE OF THE PLANT ON THE WATER REQUIREMENT.

VON SEELHORST'S EXPERIMENTS.

Von Seelhorst (1908a) experimented with lupine to determine the effect of duration of growth on the water requirement. The experiments were started on August 2, and the plants in eight pots were

¹ Von Seelhorst (1910a, p. 91) in presenting the data used in compiling Table XLV (p. 56) arranged the pots without respect to previous treatment or previous crop, in the order of decreasing yields, as follows:

Dry matter.		Water requirement, including evaporation.	
Actual.	Mean.	Actual.	Mean.
Grams.	Grams.	Grams.	Grams.
526.0		339	
482.3		685	
482.1		666	
458.5		720	
414.8		731	
399.4		777	
397.4		761	
395.5		768	
393.5		754	
390.6		763	
390.0		793	
350.5		840	
339.0		900	
	394.4		769

From these results he concludes that the water requirement increases as the production of dry matter decreases. The amount of growth was, however, greatly influenced by the fact that some pots contained more plant food than others, due to differences in the previous treatment. The unfertilized pot produced a light crop, and, as already shown in the section dealing with the effect of fertilizers on the water requirement, a deficiency in the plant-food supply greatly increases the water requirement.

It does not necessarily follow from this experiment, therefore, that the water requirement is inversely proportional to the amount of growth. These data are of value rather in showing the effect of fertilizer and of the previous crop upon the water requirement, and have been thus considered by the writers.

harvested October 8. The plants in the remaining four pots were harvested December 7. The water requirement of the pots last harvested was about 40 per cent higher than those first harvested.

These results (Table LXI) indicate that the water requirement during the later period of growth was greater than that during the earlier period of growth. Climatic conditions influence the water requirement so profoundly that it is unsafe to draw conclusions from this experiment.

TABLE LXI.—*Effect of length of the growth period on the water requirement of lupine, according to Von Seelhorst (1908a, pp. 199–201).*¹

Period.	Number of determinations.	Dry matter.	Water requirement.
Aug. 2 to Oct. 8.....	8	Grams. 310±8	216±5
Aug. 2 to Dec. 7.....	4	264±7	306±10

¹ For correction of data, see Von Seelhorst (1909). An error occurs in Von Seelhorst's paper where the water requirement for pot 5 is given as 613 instead of 316.

A uniform correction is applied for evaporation based upon the evaporation from a bare check pot, but only 70 per cent of the evaporation loss from the check pot is deducted.

The probable error includes differences due to previous treatment. One half of the pots for each period of growth were fertilized lightly in the spring and the other half heavily in the fall. Half of the pots for the short period had previously produced rye and half, potatoes. The same is true for the long-period pots, except that barley and potatoes were the previous crops. The experiment was conducted in the larger pots described on page 68.

FEST'S EXPERIMENTS.

Fest (1908) determined the water requirement of the bush bean at different times during its growth, using 72 pots, each containing 20 kilograms of soil. Ten beans were planted in each of 70 of the pots and 2 were left as checks. Shade was provided for the check pots as the crop developed. The shade was a disk of roofing paper cut radially inward from the circumference into narrow strips to a depth of 10 centimeters. Alternate strips were bent inward more or less to obtain the shade desired. Each pot was given 1 gram each of potassium, nitrogen, and phosphorus, and 2 grams of calcium carbonate. The pots were kept in the plant house during the experiment. The results (Table LXII) indicate a higher water requirement during the later periods of growth. This may be due to the period of growth, but no check was provided against a change in climatic conditions during the progress of the experiment. The later part of the experiment was conducted during the warmest months of the year and this would increase the water requirement. For this reason the experiment as conducted does not seem to the writers to be conclusive as regards the relative water requirement at different stages of growth.

TABLE LXII.—*Effect of duration of growth on the water requirement of the bush bean at Gottingen, according to Fest (1908, p. 34).¹*

Period of growth.	Condition at harvest.	Number of plants harvested.	Dry matter.	Water requirement.
			<i>Grams.</i>	
May 28 to June 19.....	Third leaf formed.....	350	255.8	134
June 20 to July 1.....	Beginning of bloom.....	229	450.8	21.
July 2 to July 10.....	End of bloom.....	150	438.4	14
July 11 to July 25.....	Fruit formed.....	104	681.3	26
July 26 to Aug. 18.....	Ripe.....	25	497.8	34

¹ Twenty kilograms of soil per pot; water content, 70 per cent of moisture-holding capacity.

VON SEELHORST'S LATER EXPERIMENTS.

The results obtained by Von Seelhorst in 1910, already given in Table LIX (p. 69), lead to the conclusion that the older growth on grassland consumes less water in proportion to the dry matter produced than does the younger growth or that following cutting. This would indicate that the results previously recorded in this section were largely an expression of climatic differences.

CONCLUSIONS.

Most of the evidence presented regarding the effect of the age of the plant on the water requirement does not seem to be conclusive, since the changes in climatic conditions have not been eliminated. Von Seelhorst's later work indicates that a nearly matured plant has a lower water requirement than a young plant.

WATER REQUIREMENT OF DIFFERENT KINDS OF PLANTS.

WOODWARD'S EXPERIMENTS.

Woodward (1699) was the first to show that different kinds of plants do not have the same water requirement. His experiments with culture solutions (p. 54) included also the determination of the water requirement of different plants grown in spring water. His results, which are based on green weight, are summarized in Table LXIII.

TABLE LXIII.—*Water requirement of plants in England, according to Woodward (1699, pp. 200-201).*

Plant.	Culture.	Number of determinations.	Green weight produced.	Water requirement based on green weight.
			<i>Grams.</i>	
Spearmint.....	Spring water.....	1	0.97	170
Solanum.....	do.....	1	3.665	65
Lathyrus.....	do.....	1	.227	715

The results are of interest chiefly because of the early date at which they were obtained. It is evident that *Lathyrus* made very little growth but continued to transpire, thus increasing its water requirement.

LAWES'S EXPERIMENTS.

Lawes (1850) was the first to make a careful comparison of the water requirement of crop plants. The results of his experiments have been discussed and are given in Table XXI (p. 31). The water requirement of the different plants measured is summarized in Table LXIV.

TABLE LXIV.—*Water requirement of crop plants in England, according to Lawes (1850, p. 54).*

Crop.	Culture.	Number of determinations.	Mean dry matter.	Water requirement.	Remarks.
			<i>Grass.</i>		
Wheat.....	Soil.....	3	25.3	225	Comparable.
Barley.....	do.....	3	27.6	262	
Clover.....	do.....	3	11.4	216	
Wheat.....	do.....	2	29.1	235	Do.
Barley.....	do.....	2	31.3	258	
Beans.....	do.....	2	34.8	214	
Peas.....	do.....	2	28.5	235	
Clover.....	do.....	2	14.2	251	

No probable error can be applied to these results, since three series of determinations were made, one with manured soil, one with unmanured soil, and one with soil containing mineral manure. The wheat, barley, and clover were treated in the same way and the results are directly comparable. The results show but little difference in the water requirement of the different crops. In the order of increasing water requirement the crops are beans, peas, wheat, clover, and barley. These results agree with those of the writers in placing the water requirement of barley above that of wheat.

WOLLNY'S EXPERIMENTS.

Wollny (1877) determined the water requirement of a number of plants. He grew the plants in small zinc cylinders of two sizes, 20 centimeters in height and either 22 or 13 centimeters in diameter. Each cylinder was provided with a cover, in the center of which a tube 2.5 centimeters long and 3 or 4 centimeters in diameter was soldered. The seeds were planted directly below the tube. The cylinders were kept on the west side of a house provided with an overhanging roof to protect them from the rain. They were weighed every three days, and the water lost was replaced. A correction was made for the water lost through evaporation from the soil by weighing pots provided with similar covers but containing no plants.

Wollny apparently used but a single pot in the case of each crop. His experiments extended through approximately four months. No determinations are given regarding the amount of grain produced. The ratio of the water transpired to the dry matter¹ produced in Wollny's experiments is given in Table LXV.

TABLE LXV.—*Water requirement of crop plants in Munich, Germany, according to Wollny (1877, p. 125).*

Crop.	Dry matter.	Water requirement.	Crop.	Dry matter.	Water requirement.
	<i>Grams.</i>			<i>Grams.</i>	
Corn.....	48.1	233	Peas.....	9.8	416
Barley.....	6.4	774	Rape.....	4.9	912
Oats.....	10.7	665	Mustard.....	5.9	843
Millet.....	5.3	447	Sunflower.....	27.8	490
Buckwheat.....	6.4	646			

SORAUER'S EXPERIMENTS.

The data presented by Sorauer (1883) which bear on the water requirement of different crop plants are given in Table LXVI.

TABLE LXVI.—*Water requirement of crop plants in Germany, according to Sorauer (1883, pp. 90-91).*

Plant.	Culture.	Duration.	Number of determinations.	Dry matter.	Water requirement.
		<i>Days.</i>			
Rye.....	Water culture.....	53	8	0.144	413
Barley.....	do.....	53	7	.327	490
Wheat.....	do.....	53	8	.068	708
Oats.....	do.....	53	8	.104	600

These data are taken from Table XLIII (p. 55), and include the two series grown in a weak nutrient solution. The results are not in accord either with our results for the four crops or with those of Lawes for barley and wheat or with Wollny for oats and barley. This may be due to the fact that the plants did not reach maturity.

HELLRIEGEL'S EXPERIMENTS.

Hellriegel (1883) conducted a series of water-requirement experiments extending over a period of seven years and including a number of crop plants. By a series of ratios Hellriegel has also compared the relative water requirement of the crops not grown simultaneously. His results for each year are given in Table LXVII and the mean values are given in the last column.

¹ It is not clear from Wollny's description whether the term refers to air-dried or oven-dried material.

TABLE LXVII.—*Water requirement of plants at Dahme, Germany, according to Heltriegel (1883, pp. 641-661).¹*

Crop.	1867		1868		1869		1870		1871		1872		1873		Summary.		Relative water requirement compared with barley. ²					
	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Water re-quire-ment.	Num-ber of deter-mina-tions.	Mean	1867	1868	1871	1872	1873	Mean.
Barley.....	13	285±5	25	366±3	5	305±7	13	263±4	6	286±7	6	318±10	6	347±6	74	297	100	100	100	100	100	100
Oats.....	24	338±5	16	464±4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	451	115	127	.....	.....	121
Summer wheat.....	20	328±5	15	380±5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	41	359	111	107	.....	.....	119
Summer rye.....	20	315±4	15	438±7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	41	377	107	120	.....	.....	114
Horse beans.....	.....	.....	.....	.....	.....	.....	.....	.....	3	261±4	0	264±9	.....	.....	9	273	.....	.....	91	83	.....
Yellow lupine.....	.....	.....	.....	.....	.....	.....	.....	.....	3	319±11	8	277±4	2	353±9	11	373	.....	.....	112	124	127
Peas.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8	231±4	8	287±14	10	292	.....	.....	.....	73	102
Red clover.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8	263±12	8	297±14	16	330	.....	.....	.....	114	86
Red clover.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	371±3	.....	.....	7	371	.....	.....	.....	117	117
Buckwheat.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	337±9	.....	.....	3	337	.....	.....	.....	106	106
Summer rape.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

¹ The evaporation was estimated by check pots from 1867 to 1870; from 1871 to 1873 the pots were covered to prevent evaporation: 4 kilograms of sand per pot were used.² In the summary given by Heltriegel (1883, pp. 663) the water requirement of barley for 1871 is erroneously given as 264 instead of 286. Because of this error his summary does not conform exactly to the summary of his results here given.

Previous to 1871 the experiments were conducted in open jars containing about 4 kilograms of sand. Check pots were used to estimate the loss by evaporation. In 1871 and during succeeding years the soil was covered with a board infiltrated with a wax and paraffin mixture, which greatly reduced the direct evaporation. The crops grown during the year 1867, arranged in the order of increasing water requirement, are barley, rye, wheat, and oats. During the year 1868 the water requirement of all the crops was higher than in 1867. In 1871 the horse bean had the lowest requirement, followed by barley and yellow lupine in order. The order of these crops was the same in 1872. The crops grown in 1872 arranged in order of increasing water requirement are pea, horse bean, barley, rape, red clover, buckwheat, and yellow lupine. The results in 1873 as compared with those of the same crops grown during 1872 shows the order to be exactly reversed. The differences are small in most cases, when the probable error is considered.

A comparison of the results in the last column of Table LXVII shows the water requirement of barley and of red clover to be the same, wheat 9 per cent higher, rye 14 per cent higher, and oats 21 per cent higher than barley. Of the other crops, the horse bean and pea have the lowest water requirement, while the remaining crops exceed the water requirement of barley.

KING'S EXPERIMENTS.

During the years 1891 to 1894 King (1892 to 1895) conducted a series of experiments dealing largely with the relative water requirements of different crops. Correction was made for rainfall, but not for evaporation. King does not give the results of his duplicate determinations except for corn, the other results being expressed as mean values. The comparable results are shown in Table LXVIII.

TABLE LXVIII.—*Water requirement of crop plants in Wisconsin, according to King (1889 to 1895).*¹

Crop.	1891		1892		1893		1894		Summary. Mean water requirement.	Relative water requirement compared with oats.			
	Number of pots.	Water requirement.	Number of pots.	Water requirement.	Number of pots.	Water requirement.	Number of pots.	Water requirement.		Crop.	1891	1892	1894
Dent corn ² ...	2	306±5	2	318±68	2	390±91	4	504±25	4	Oats.....	100	100	100
Flint corn.....	2	502±6	2	526	2	390±91	2	390	2	Barley.....	80	71	.....
Oats.....	2	401±2	2	375	2	390±91	2	388	2	Dent corn ² ...	61	60	.....
Barley.....	2	401±2	2	477	2	390±91	2	477	2	Field pea.....	.....	91	.....
Field pea.....	2	401±2	2	564	2	390±91	2	481	2	Red clover.....	.....	107	.....
Red clover.....	2	401±2	2	564	2	390±91	2	481	2	Potatoes.....	.....	.....	71
Potatoes.....	2	401±2	2	564	2	390±91	2	423±6	2				

¹ In this table the writers have endeavored to eliminate errors in comparison. Consequently, they have omitted the determinations which were specially fertilized and have not used a weighted mean in the summary. The experiments in 1891 were made in 50-gallon barrels, painted and sunk level with the surface of the ground. In 1892 galvanized cans 18 by 40 inches were used in place of the barrels. In 1894 the plants and pots were protected from rain by a temporary cover of heavy duck. The potato cans were 18 by 24 inches.

² Pride of the North variety used.

³ For an error in King's data in connection with this value, see Table XXV (p. 35).

⁴ There were two pots, but the results are given only as a mean.

From these results it would appear that the water requirements of oats, clover, and field peas are about the same. Potatoes and barley have a somewhat lower water requirement, and dent corn requires about 40 per cent less water than oats for the production of an equal amount of dry matter.

VON SEELHORST'S EXPERIMENTS.

Most of the experiments conducted by Von Seelhorst were for the purpose of determining the effect of various environmental factors on the water requirement. In his experiments, published in 1906 and 1908, different crops were grown simultaneously under comparable conditions, as shown in Table LXIX. The experiments with rye, barley, and potatoes were conducted in the large pots described on page 68.

TABLE LXIX.—*Water requirement of crop plants at Gottingen, Germany, according to Von Seelhorst (1906, 1908, and 1908a).¹*

Series, date of publication, and page reference.	Crop.	Soil type.	Number of determinations.	Dry matter.	Water requirement.	Period of growth.
First series, 1906, p. 329.....	Wheat....	Loam...	1	Grams. 942	333	Oct. 8, 1904, to Aug. 2, 1905.
	Rye.....	do....	1	700	375	Oct. 8, 1904, to Aug. 3, 1905.
	Potatoes...	do....	1	1,173	* 268	Apr. 26 to Oct. 10, 1905.
Second series, 1906, pp. 340-342..	Rye.....	Sand....	2	364	480	Aug. 10, 1904, to Aug. 2, 1905.
	Barley....	do....	1	457	454	Mar. 29 to Aug. 2, 1905.
	Potatoes...	do....	3	* 1,685	* 60	Apr. 26 to Aug. 3, 1905.
Third series, 1908, pp. 195-197...	Rye.....	Loam...	1	883	307	Oct. 17, 1906, to Aug. 12, 1907.
	Barley....	do....	1	827	346	Mar. 30 to Aug. 12, 1907.
	Beets.....	do....	1	823	268	May 11 to Nov. 5, 1907.
Fourth series, 1908a, pp. 203-207.	Potatoes..	Sand....	6	286	294	Apr. 24 to Aug. 7, 1907.
	Rye.....	do....	4	343	383	Oct. 12, 1906, to Aug. 7, 1907.
	Barley....	do....	2	457	295	Mar. 30 to Aug. 7, 1907.

¹ The experiments were mainly conducted in square-meter pots (p. 68). The data in each group are comparable, but the different groups can not be intercompared. In the last series half of the determination for each crop is from pots that received heavy fertilizer in the fall and half that received light fertilizer in the spring. (See Table XLV, p. 74.) Each pot produced a crop of lupine in the late summer and fall of 1906. The probable error is therefore not given. The second series, rye, barley, and potatoes, grown in 1905, were all in pots which were given a light application of manure in the spring.

* Water requirement based on green weight, 66.

* Green weight or based on green weight.

TABLE LXIX.—*Water requirement of crop plants at Gottingen, Germany, according to Von Seelhorst (1906, 1908, and 1908a)—Continued.*

RELATIVE WATER REQUIREMENT COMPARED WITH RYE.

Crop.	First series.	Second series.	Third series.	Fourth series.
Rye.....	100	100	100	100
Barley.....		95	112	77
Potatoes.....	72			77
Wheat.....	89			
Beets.....			87	

According to the above figures, rye and barley have about the same water requirement. Potatoes have a water requirement three-fourths that of rye, while wheat and beets are intermediate.

WIDTSOE'S EXPERIMENTS.

Widtsøe (1909) gives the average water requirement found for each of the crops used during the 4-year period covered by his experiments. (Table XVII, p. 28.) The results obtained using "College loam" soil may be considered as representing the water requirement of crops at Logan, Utah, when grown in productive soils. Widtsøe gives the following values for the water requirement of crops in this soil: Corn, 386; wheat, 546; sugar beets, 497; and peas, 843. These results are in agreement with those obtained by the writers in north-eastern Colorado, with the exception of sugar beets, the water requirement of which is 32 per cent higher than the ratio obtained there.

LEATHER'S EXPERIMENTS.

Leather (1910, 1911) has measured the water requirement of a number of crops at Pusa, India. His experiments were carried on in glazed stone jars of various sizes, 9 or 12 inches in diameter and from 12 to 22 inches in depth, ranging in capacity from 12 to 48 kilograms of soil. The jars were not covered, the loss of water from the soil being estimated by the use of check jars in which no plants were grown. When a number of crops were grown in the same soil, four blank jars, two of which contained manured soil, were used, and the arithmetical mean of the losses taking place from the four jars was assumed to represent the amount of water which evaporated directly from the soil during the experiment.¹

¹ Leather cites in illustration four blank jars which lost 9.93, 10.68, 13.03, and 14.11 kilograms, respectively, during the growing period. He states that the differences are not attributable to the presence of manure. The probable error of a single determination as calculated from the above figures is 1.6 kilograms. The water transpired by jars with different treatments during the period covered by the above figures is as follows: Unfertilized, 3.4 and 6.7 kilograms; with nitrogen, 6.2 and 7.1 kilograms; with nitrogen and phosphoric acid, 36.1 and 28.1 kilograms. The probable error of the evaporation correction thus amounts to about 5 per cent of the total transpiration in the case of the thrifty plants. With the unfertilized plants it is 47 and 24 per cent, respectively. This uncertainty arises from the differences in the evaporation from blank jars even when they are treated alike. A further error which can not be estimated results from the fact that the soil in the culture pots is shaded and dried by the plants growing in it.

The jars were supported on small cars, which ran on tracks extending to the culture house from an inclosure covered with wire netting. During the day when the weather was good the jars occupied the screened inclosure. At night and during wet weather they were brought under cover.

The jars were weighed each morning, which was accomplished by a large beam scale sensitive to 5 grams with a maximum load of 100 kilograms. By means of a cross track, jars from any track could be brought under the balance for weighing.

Water was added through unglazed earthenware cylinders about 5 centimeters in diameter and from 15 to 20 centimeters deep, provided with small holes in the bottom and the lower part of the sides. These cylinders were fixed in position in the center of the jar, so that the upper edge coincided approximately with that of the sides of the jar. By watering through these cylinders the surface soil remained loose, friable, and nearly air-dry, and cracking was avoided. The direct loss of water from the soil was also much reduced, being only about one-third as much as when the water is added to the surface of the soil. The roots were not found to be unusually abundant about the cylinders. Clean well water was used for watering the plants.

Fertilizers, when used, were added either in the dry state to the air-dried soil or were dissolved in the water used for dampening the soil before filling the pots. The weight of the plants after drying at about 100° C. was used in the final calculation of the water requirements. A summary of Leather's results is given in Table LXX.

TABLE LXX.—Relative water requirement of crop plants at Pusa, India, based on results of soils fertilized with $N+P$ and $N+P+K$, according to Leather (1910 and 1911).

Crop.	Total number pots used in tests.	Mean water requirement.	Crop.	Total number pots used in tests.	Mean water requirement.
Cold-weather crops:			Monsoon crops—Continued.		
Wheat (<i>Triticum sativum</i>)	23	544 ± 10	Juar (<i>Andropogon sorghum</i>)	2	437 ± 41
Barley (<i>Hordeum vulgare</i>)	4	468 ± 12	Murwa (Ragi millet, <i>Echinochrome coracana</i>)	2	263 ± 2
Oats (<i>Avena sativa</i>)	4	469 ± 40	Kodo (Kodo millet, <i>Paspalum scrobiculatum</i>)	.....	312 ± 4
Linseed (<i>Linum usitatissimum</i>)	6	807 ± 49	Rahar (pigeon-pea, <i>Cajan indicum</i>)	4	635 ± 15
Sarson (kai, <i>Brassica campestris</i>)	6	496 ± 32	Guar (<i>Cyamopsis psoraleoides</i> , <i>C. tetragonoloba</i>)	2	596 ± 5
Pea (<i>Pisum sativum</i>)	4	563 ± 28	Rice (<i>Oryza sativa</i>)	2	811 ± 11
Gram (chick-pea, <i>Cicer arietinum</i>)	4	818 ± 77	Sugar cane (<i>Saccharum officinarum</i>)	2	212 ± 1
Monsoon crops:					
Maize (<i>Zea mays</i>)	31	337 ± 5			

The cold-weather crops have a higher average water requirement than the monsoon crops. Barley and oats have the same water requirement, while wheat is about 16 per cent higher. Chick-peas, rice, and linseed have the highest water requirement, which is nearly four times that of the lowest, sugar cane. Next in efficiency to the sugar cane are millet, corn, and sorghum.

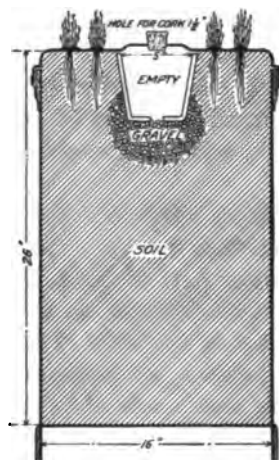


FIG. 5.—Pot used by Briggs and Shantz (1913) in measuring the water requirement of plants.

The plants were grown in large galvanized-iron cans containing about 115 kilograms of soil. All direct evaporation from the soil was practically eliminated by tight covers and by sealing the openings around the stems of the plants with wax (fig. 5). The method of watering is shown in figure 6. In order to determine the probable error of the results, six pots were used in each determination. Over 200 cans were employed in the experiments at Akron in 1911, including tests with 30 varieties of crop plants. The results are summarized in Table LXXI.

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BRIGGS AND SHANTZ'S EXPERIMENTS.

The writers (1913) have measured the water requirement of plants in the Great Plains at Akron, Colo., and at Dalhart and Amarillo, Tex. For a comparison of the results at Akron and the Texas stations the reader is referred to Table LI (p. 61).

The plants were grown in large galvanized-iron cans contain-

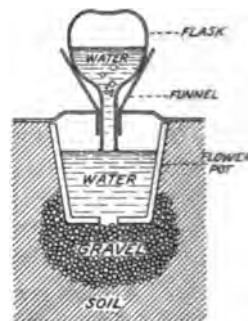


FIG. 6.—Sketch showing the device used by Briggs and Shantz (1913) in adding water to the pots.

WATER REQUIREMENT OF DIFFERENT KINDS OF PLANTS. 81

TABLE LXXI.—*Summary of water-requirement measurements of varieties and crops at Akron, Colo., 1911, according to Briggs and Shantz (1913, p. 47).*

BASED ON WEIGHT OF DRY MATTER PRODUCED.

Crop.	Variety.	Water requirement.		
		Variety.	Crop.	Relative, compared with wheat.
Alfalfa.....	Grimm.....	1068±16	1,068	211
Peas.....	Canada.....	800±17	800	158
Artemisia frigida.....	765±24	765	151
Rye.....	Spring.....	724±7	724	143
Sweet clover.....	709±9	709	140
Oats.....	{ Burt.....	639±7	614	122
	{ Swedish Select.....	615±7		
	{ Sixty-Day.....	605±5		
	{ Canadian.....	598±14		
Buckwheat.....	578±13	578	114
Barley.....	{ Beardless.....	544±9	539	106
	{ Beldi.....	543±2		
	{ White Hull-less.....	542±3		
	{ Hannchen.....	537±8		
Wheat.....	{ Emmer.....	534±14	507	100
	{ Bluestem.....	531±5		
	{ Spring Ghirka.....	506±3		
	{ Galgalos.....	496±4		
	{ Kubanka.....	468±8		
Potatoes.....	Irish Cobbler.....	448±11	448	88
Rape.....	441±12	441	87
Sugar beets.....	Kleinwanzleben.....	377±8	377	74
Corn.....	{ Iowa Silvermine.....	420±3	399	73
	{ Northwestern Dent.....	368±10		
	{ Esperanza.....	319±5		
Weeds.....	{ Amaranthus retroflexus.....	356±4	322	63
	{ Salsola pestifer.....	336±5		
	{ Amaranthus graecizans.....	275±7		
Sorghum.....	{ Dwarf milo.....	333±3	306	60
	{ White durra.....	321±2		
	{ Brown kaoliang.....	301±3		
	{ Red amber.....	298±4		
	{ Blackhull kafir.....	278±5		
Millet.....	{ Kurak.....	287±2	275	54
	{ German.....	263±15		

BASED ON WEIGHT OF GRAIN PRODUCED.

Peas.....	Canada.....	2218±100	2,218	163
Rye.....	Spring.....	2215±37	2,215	163
Oats.....	{ Canadian.....	2204±140	1,680	124
	{ Swedish Select.....	1632±35		
	{ Burt.....	1500±57		
	{ Sixty-Day.....	1363±30		
Wheat.....	{ Bluestem.....	1786±60	1,357	100
	{ Spring Ghirka.....	1362±43		
	{ Galgalos.....	1245±13		
	{ Kubanka.....	1191±14		
	{ Emmer.....	1180±42		
Barley.....	{ White Hull-less.....	1475±40	1,244	92
	{ Beardless.....	1210±38		
	{ Beldi.....	1155±18		
	{ Hannchen.....	1134±27		
Buckwheat.....	1037±33	1,037	76
Millet.....	Kursk.....	923±40	923	68
Sorghum.....	{ Dwarf milo.....	1123±57	790	58
	{ White durra.....	806±12		
	{ Blackhull kafir.....	803±26		
	{ Brown kaoliang.....	726±12		

Of the crops tested, those most efficient in the use of water are the millets, the sorghums, and the corns, their water requirement ranging from 275 to 370. The legumes, alfalfa, sweet clover, and Canada pea, have the highest water requirement, ranging from 710 to 1,070, while the small grains, wheat, barley, oats, and rye, have a water requirement ranging from 510 to 700. Potatoes and sugar beets are intermediate between the small grains and the corns. The efficiency of the grain sorghums and millet is again apparent in grain production. Spring rye and Canada peas are least efficient, while oats, wheat, barley, and buckwheat are intermediate. Varieties of barley, wheat, oats, and sorghum show great differences in the water requirement for grain production.

In the investigations which have been discussed heretofore the determinations of the water requirement have been limited to different crops. In this investigation the water requirement of different varieties of the same crop was also determined, and measurable differences were found. These varietal differences suggest not only the superiority of certain strains but also the desirability of applying water-requirement measurements in the selection of varieties for semiarid regions.

CONCLUSIONS.

In comparing the results obtained by different investigators relative to the water requirement of different species of plants, two points should be kept in mind: (1) A real difference in the results is to be expected if the climatic conditions differ at the places where the experiments were conducted. From this point of view the observed differences in the water requirement may be looked upon as a measure of the climatic differences. (2) Differences due to the method of experiment, to the use of different varieties, to the amount of plant food available, to the period during which the crop was grown, and to other similar factors must be classed as experimental errors in a comparison of this kind. The summary of the results of different investigators as presented in Table LXXII should then be considered with the points mentioned above in mind. Often the results are not strictly comparable, even when forming part of the same investigation, owing to differences in the duration or period of growth, and the more detailed statement given elsewhere in the bulletin should be referred to in this connection.

TABLE LXXII.—*Summary of water requirement determinations for different crops as influenced by climate.¹*

Crop.	Lawes, 1850, Rotham- sted, Eng- land.	Wollny, 1876, Munich, Ger- many.	Hell- riegel, 1883, Dahme, Ger- many.	King, 1892-1895, Madison, Wis.	Von Seel- horst, 1896-1898, Gott- ingen, Ger- many.	Widtsoc, 1900, Logan, Utah.	Leather, 1910-11, Pusa, India.	Briggs and Shantz, 1913, Akron, Colo.
Wheat.....	235		359		333	546	554	807
Oats.....		665	401	541			469	614
Barley.....	258	774	297	388	365		468	539
Rye.....			377		386			724
Corn.....		233		350		386	337	369
Sorghum.....							437	305
Millet.....		447						275
Beans.....	214							
Peas.....	235	416	292	477		843	563	800
Clover (red).....	251		330	481				
Clover (sweet).....								709
Alfalfa.....								1,068
Horse beans.....			263					
Lupine.....			373					
Chick-peas.....							818	
Buckwheat.....		646	371					578
Rape.....		912	337					441
Mustard.....		843					486	
Sunflower.....		490						
Potatoes.....				423	281			448
Linseed.....							807	
Eleusine.....							263	
Paspalum.....							312	
Cajana.....							635	
Cyamopsis.....							508	
Rice.....							811	
Sugar cane.....							212	
Sugar beets.....						497		377
Salsola.....								336
Amaranthus.....								303
Artemisia.....								765

¹ Summarized with respect to crops without respect to varieties. Includes only crops grown to maturity. The data are not strictly comparable, even in the case of a single investigation. The reader should consult the detailed discussion of each investigation in the earlier portions of this bulletin.

Lawes, working in England, obtained a lower value for the water requirement than any other investigator. Hellriegel and Von Seelhorst, in Germany, both obtained comparatively low values, while Wollny's results are comparatively high. King, working in Wisconsin, obtained lower values than the writers obtained in northeastern Colorado. Widtsoc's results at Logan, Utah, agree closely with those of the writers, being from 4 to 7 per cent higher for all crops except the sugar beet, which was 32 per cent higher. Leather, at Pusa, India, obtained lower values for oats, barley, corn, and peas, but higher values for wheat and sorghum than did the writers. Wollny's results are higher than the writers' in every case where the same crop was grown, with the single exception of corn.

The relative positions of the different crops vary greatly in the different investigations. Wheat and barley alternate, wheat having the higher water requirement in Hellriegel's and Leather's determinations and barley ranking higher in Lawes's, Von Seelhorst's, and

the writers' measurements. Rye has a higher water requirement than wheat or barley in every case. The water requirement of oats is higher than barley in all cases except in Wollny's determinations. Peas gave a water requirement lower than barley in all cases except Leather's and the writers'. The water requirement of potatoes was lower than barley in all cases except in King's determination.

DETERMINATION OF THE WATER REQUIREMENT OF CROPS UNDER FIELD CONDITIONS.

CROPS GROWN WITH IRRIGATION.

WIDTSOE'S EXPERIMENTS.

Widtsøe (1912) conducted an extensive field experiment for the purpose of determining the effect of different amounts of irrigation water upon the water requirement. A number of crops were employed in the investigations. The results are given in Table LXXIII, the amount of irrigation water applied being given in the first column of the table. In addition to this irrigation water, there was available to each crop the rainfall of the season, which amounted to about 5 inches, and also the water which was stored in the soil at the beginning of the season as the result of the winter rains. From earlier measurements Widtsøe has calculated the average amount of stored water removed from the soil by each of the crops tested. The sum of the rainfall and the stored moisture used by each crop, according to Widtsøe's calculations, is given at the bottom of the table. This sum was added to each amount of irrigation water applied in calculating the water requirement of the crop. This procedure assumes that the soil-moisture content was the same at the end of the season in all of the plats devoted to a given crop without reference to the amount of irrigation water which had been applied during the season and which varied from 4 to 70 inches. It is unfortunate that moisture determinations were not made in each plat at the beginning and at the end of the season in order to avoid the uncertainty arising from this assumption.

TABLE LXXIII.—*Effect of different amounts of irrigation water on the water requirement of crops under field conditions, according to Widtsoe (1912, pp. 55-57).*

Water applied.	Water requirement, including evaporation, for—									
	Wheat.	Oats.	Barley.	Corn.	Alfalfa.	Sugar beets.	Carrots.	Potatoes.	Cabbage.	Onions.
Irrigation water added, in acre-inches:										
3.75							423			
5	856	596				569		1,136		
7.5	899		513	276			557	1,136		
10	948	572		275	621	571		1,255		
12.5									2,214	
15	1,038	845	696	356	977	663	572	1,411		2,170
20		897		416	946	682		1,466	3,128	2,628
25	1,317		998	474	1,052		760		4,248	
30				527	1,253	889		2,242		2,485
35	1,530						880			
39.5			1,263							
40									5,068	
45		1,566						3,060		
50	1,809				1,480	1,186				
55				1,067						
60							1,071	3,292		
65										4,689
70									7,419	
Soil water and rainfall used by crop in addition to irrigation:										
Inches.....	13.74	9.66	9.66	5.54	14.91	10.28	10.25	6.17	5.54	5.54

Widtsoe's results show clearly the great increase in the water requirement, which includes the evaporation as well, when the quantity of irrigation water applied is increased, the largest amounts of water applied resulting in a water requirement of about three times that observed when small quantities of irrigation water were used.

CROPS GROWN WITHOUT IRRIGATION.

LEATHER'S EXPERIMENTS.

Leather (1911) also measured the water requirements of a number of crops under field conditions. The land selected for the purpose was kept fallow during the rainy (monsoon) season, and the crops were sown at the beginning of the dry season. Moisture determinations were made in each plat soon after the plants were above ground and again at harvest. The difference in the amount of water in the soil at the time of these two measurements plus the water added through rainfall represented the total loss of water. The rainfall during the experimental period was very low, being only 0.4 inch at Pusa in 1908-9 and 0.2 inch in 1909-10, making the conditions exceptionally favorable for an experiment of this kind. Moisture determinations at seeding time and at harvest were also made in a part of the field which was kept fallow throughout the experiment. The difference in these determinations gave the loss due to evaporation from the fallow plat. The evaporation loss from the cropped plats was assumed to be the same as from the fallow plat. The difference between the total amount of water lost and that lost through evapora-

tion was ascribed to the transpiration of the crop. This, divided by the dry matter produced, gave the water requirement. The crops grown were heavy, amounting to 5,000 pounds or more per acre in the case of the cereals. About 50 square feet were harvested for determining the dry matter produced. The area of this sample included the point where the initial moisture determination was taken. Moisture samples were taken to a depth of 9 feet. Table LXXIV shows the results of Leather's field determinations of the moisture requirement and includes also some determinations of the water requirement of wheat grown under irrigation at Cawnpore, India.

TABLE LXXIV.—*Water requirement of crops in India grown under field conditions, according to Leather (1911, pp. 234-279).*

Crop.	Station.	Year.	Rainfall during experiment.	Water requirement.	
				No manure.	Manure.
			<i>Inches.</i>		
Wheat.....	Pusa.....	1908-9	0.38		415
	do.....	1909-10	.22	237	313
	Cawnpore.....	1908-9	.25	442	
	do.....	1908-9	.25	550	
Wheat (irrigated).....	do.....	1909-10	1.81	407	
	do.....	1909-10	1.81	302	
Barley.....	Pusa.....	1908-9	.38	430	341
	do.....	1907-8	2.8	411	
Oats.....	do.....	1908-9	.38	331	230
	do.....	1909-10	.22		282
	do.....	1908-9	.38	693	718
Linseed.....	do.....	1909-10	.22	706	940
Peas.....	do.....	1908-9	.38	314	505
	do.....	1908-9	.32	471	298
Mustard.....	do.....	1909-10	.16	477	614

Unfortunately, Leather's experiments were, for the most part, conducted upon a single plat in each case. It is consequently not possible to form any definite conception of the probable error of the experiments. Results from duplicate plats are, however, available in the case of the irrigated wheat grown at Cawnpore, and the probable error for a single determination is, in the case of these results, 12 per cent and 17 per cent, respectively, of the observed water requirement. It is therefore evident that a relatively large observational error is to be expected in this method of determining the water requirement. Some of the anomalies appearing in the results, notably the higher water requirement obtained in some cases when manure is used, are probably to be ascribed to experimental error. From investigations now in progress regarding the loss of water from fallow lands in the Great Plains, the writers are inclined to believe that the direct evaporation from the soil of the fallow land is considerably greater than the corresponding loss from the soil of the cropped plats. The soil of the cropped plats is not only shaded by the growing crop, but is also considerably protected from wind, so that the humidity of the air is

relatively higher immediately above the soil surface than over the fallow land. The crop in its early stages also dries out the surface soil, so that the water content of the upper layers of the cropped plat is materially lower than the fallow land. This would tend to reduce the evaporation loss from the cropped plat. It would consequently appear that the correction term for the evaporation loss from the cropped plats is somewhat too large, which would tend to give too low a value for the water requirement under field conditions. It will be noted that the values obtained in the field experiments are, almost without exception, below the mean water requirement obtained from the pot experiments. (Table XL, p. 52.) Leather calls attention, however, to the fact that in the latter determinations small pots were used in a part of the experiments, which tend to give too high a value for the water requirement. He also suggests as a possible source of error the capillary rise of water from below the 9-foot level in the field experiments, but believes the error due to an unmeasured water supply from this source to be very small. The field experiments of the writers fully support him in this conclusion.

BRIGGS AND SHANTZ'S EXPERIMENTS.

The writers' measurements of the water requirement of wheat under field conditions at Akron, Colo., were based upon the water removed by the crop as shown by the difference between the initial and final water content combined with the rainfall entering the soil, determined by daily sampling. No correction for evaporation was attempted. The results are summarized in Table LXXV. The water requirement of wheat grown in the field was found by this procedure to be higher than that obtained in the pot measurements. However, when the rainfall during the growth of the crop was not considered, the water requirement of the wheat grown under field conditions agreed closely with that obtained in the pot cultures. The writers attribute this to the fact that the wheat was drawing its supply of moisture from the subsoil at the time of these rains, and failed to develop a surface root system in time to absorb the rainfall before it evaporated.

TABLE LXXV.—*Comparison of water requirement of Kubanka wheat crops grown under field conditions, 1910 and 1911, according to Briggs and Shantz (1913, p. 41).*

Character of experiments.	Water requirement.			
	Including rainfall during growth.		Excluding rainfall.	
	Based on dry matter.	Based on grain.	Based on dry matter.	Based on grain.
Field experiments, 1910.....	700	2,315	496	1,780
Field experiments, 1911.....	862	2,380	466	1,614
Pot experiments, 1911.....			468 ± 8	1,196 ± 15

CONCLUSIONS.

The measurement of the water requirement under field conditions is uncertain, owing to the difficulty of determining what proportion of the rainfall during the growing season is actually used by the crop. This uncertainty arises from a lack of knowledge regarding the amount of run-off and the amount of rainfall that is evaporated from the soil surface without becoming available to the crop. The production of the crop upon water stored in the subsoil during a period without rain, as in Leather's experiments, is an ideal condition for field measurements of this kind. Under these conditions Leather obtained a lower water requirement in the field experiments than in the pot cultures. The writers found that the water requirement was higher under field conditions than in pot cultures if the rainfall during the growing period was taken into consideration, but that the determinations agreed closely if the light rainfall that occurred during the growing season was ignored.

SUMMARY.

The term "water requirement" is used in this paper to indicate the ratio of the weight of water absorbed by a plant during its growth to the dry matter produced.

The experiments made in connection with the effect of soil-moisture content on the water requirement show, as a rule, an increase in the water requirement when the soil-moisture content approaches either extreme. Many of these experiments were conducted in open pots and the direct evaporation estimated from check pots without plants. Owing to the uncertainty of this method when a wide range in soil-moisture content is employed and to the difficulty of securing a uniform distribution of soil moisture when the soil is maintained at a low water content, it would appear that the direct effect of soil-moisture content on the water requirement is still an open question.

Many investigations have been made regarding the effect of fertilizers on the water requirement, and with few exceptions the experiments show a reduction in the water requirement accompanying the use of fertilizers. In highly productive soils this reduction is slight. In poor soils the water requirement may be reduced one-half, or even two-thirds, by the use of fertilizers. Often a high water requirement is due to a deficiency of a single plant-food element. As the supply of such an element approaches exhaustion, growth practically ceases, while the transpiration continues, which leads to a high water requirement. This emphasizes the importance of maintaining the fertility of the soils of the semiarid regions if the most effective use is to be made of the limited water supply.

As a whole, the investigations relative to the effect of fertilizers on the water requirement show clearly that transpiration is not a measure of growth, even under the same atmospheric conditions, since the water requirement is profoundly affected by the plant food available in the soil.

The type of soil used may affect the water requirement in so far as it determines the amount of plant food available to the crop. There is no indication that the texture of the soil, independently of the plant food it contains, affects the water requirement of plants.

The water requirement is influenced by limiting the amount of soil available to the roots of the plants, the water requirement decreasing within limits as the amount of soil is increased. This would follow as a result of an inadequate supply of plant food. In some cases the water requirement has been increased as a result of previous cropping. This would follow from the reduction of the available supply of plant food by the previous crop.

No direct measurements have been made of the effect of soil temperature on the water requirement. Leather found, however, that an increase in the soil temperature due to the sun shining on the pots did not materially affect the water requirement.

The water requirement has been shown to be profoundly affected by the atmospheric conditions. The water requirement of the same crop varies greatly according to the period of the year in which it is grown. Similarly, the same crop will give a widely differing water requirement when grown in different regions during the same period.

All of the investigations which have so far been made indicate that shading increases the water requirement. This would follow if the shade were so dense as to reduce photosynthesis.

The water requirement is greater in dry than in moist air. Montgomery and Kiesselbach have found the water requirement of corn to be proportional to the evaporation from a small free water surface. From their data the writers have shown that the water requirement was approximately proportional to the saturation deficit of the air.

Soraauer found the water requirement to increase when the carbon-dioxid content of the air was diminished, which is analogous to a deficiency in mineral plant food.

Wimmer has shown that the water requirement of sugar beets and celery is increased by the attacks of parasitic nematodes. The infested plants grow more slowly, which would account for the increase in the water requirement.

Montgomery has compared the water requirement of narrow-leaf and broad-leaf types of corn, and found that the narrow-leaf strain had a lower water requirement. It is, however, possible that this difference may have been due to a superior varietal efficiency of the narrow-leaf type independent of its leaf area.

Von Seelhorst's experiments on the effect of frequent cutting indicate that grassland can produce dry matter more efficiently than pasture land. In other words, the water requirement of the grasses is apparently higher during the earlier stages of growth than at any other time. These experiments, however, include the loss due to direct evaporation from the soil, which might be greater during the earlier stages of the crop.

A summary of the water-requirement measurements which have been made with different crops is given in Table LXXVI. The variation in the water requirement of the same crop as determined by different investigators is due largely to soil and climatic conditions, but probably in part also to the use of different varieties as well as to experimental errors. The data given in the same investigation are not always strictly comparable, since the crops were not all grown during the same period.

TABLE LXXVI.—*Summary of the water-requirement measurements for various crops, as determined by different investigators.*

Crop.	Lawes, 1850, Rotham- sted, England.	Wolny, 1886, Munich, Ger- many.	Hellrie- gel, 1883, Dahme, Ger- many.	King, 1892 to 1896, Madison, Wis.	Von Seelhorst, 1896 to 1898, Got- tingen, Ger- many.	Widtsøe, 1909, Logan, Utah.	Leather, 1910-11, Pusa, India.	Briggs and Shantz, 1913, Akron, Colo.
Wheat.....	235		359		333	546	554	507
Oats.....		608	401	541			480	614
Barley.....	258	774	297	388	365		468	530
Rye.....			377		386			724
Corn.....		233		350		386	337	369
Sorghum.....							437	306
Millet.....		447						275
Beans.....	214							
Peas.....	235	416	292	477		843	563	800
Clover (red).....	251		330	481				709
Clover (sweet).....								1,068
Alfalfa.....								
Horse beans.....			263					
Lupine.....			373					
Chick-peas.....							818	
Buckwheat.....		646	371					578
Rape.....		912	337					441
Mustard.....		843					496	
Sunflower.....		490						
Potatoes.....				423	281			448
Linseed.....							807	
Eleusine.....							263	
Paspalum.....							312	
Cajanna.....							635	
Cyamopsis.....							598	
Rice.....							811	
Sugar cane.....							212	
Sugar beets.....						497		377
Salola.....								336
Amaranthus.....								303
Artemisia.....								766

One of the most striking features of water-requirement measurements is the marked difference in efficiency exhibited by different plants in the use of water. The millet, sorghum, and corn groups have been found the most efficient, while alfalfa and sweet clover are

the least efficient in producing dry matter with a given amount of water. The small-grain crops have a water requirement intermediate between the legumes and corn. Measurable differences in the water requirement also exist between different varieties of the same crop, and this suggests the possibility of developing through selection strains which are still more efficient in the use of water.

Leather found that the water requirement of a crop grown under field conditions was, as a rule, lower than the water requirement of the same crop determined from pot experiments. The writers' measurements of the water requirement of wheat under field conditions gave a higher value than the corresponding pot determinations. If, however, the calculations were based upon the amount of stored moisture removed by the crop without reference to the rainfall received during the growing season, the field results were in close agreement with the pot experiments.

LITERATURE CITED.

Cited in this
bulletin on
page—

- BRIGGS, L. J., and SHANTZ, H. L.
1913. The water requirement of plants. I.—Investigations in the Great Plains in 1910 and 1911. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 284, p. 49 60, 61, 80, 87
- BURGERSTEIN, ALFRED.
1904. Die Transpiration der Pflanzen. Jena, pp. 154–158..... 11
- DASZEWSKI, A. VON.
1900. Der Einfluss des Wassers und der Düngung auf die Zusammensetzung der Asche der Kartoffelpflanze. Journal für Landwirtschaft, Bd. 48, Heft 3, pp. 223–249..... 15, 39
- DEHÉRAIN, P. P.
1892. La transpiration des végétaux et l'emploi des engrais. Annales Agronomiques, t. 18, pp. 465–486..... 34
- FEST, FRANZ.
1908. Über den zeitlichen Verlauf der Nährstoffaufnahme und Trockensubstanzproduktion bei der Buschbohne unter verschiedenen Düngungs- und Witterungsverhältnissen. Journal für Landwirtschaft, Bd. 56, Heft 1, p. 1–47, 1 fig., pl. 1–5..... 71
- FITTBÖGEN, J.
1873. Untersuchungen über das für eine normale Produktion der Haferpflanze nothwendige Minimum von Bodenfeuchtigkeit, sowie über die Aufnahme von Bestandtheilen des Bodens bei verschiedenem Wassergehalt desselben. Landwirtschaftliche Jahrbücher, Bd. 2, pp. 353–371, 1 fig..... 12
1874. Ueber die Wasserverdunstung der Haferpflanze unter verschiedenen Wärme-, Licht- und Luftfeuchtigkeits-Verhältnissen. Landwirtschaftliche Jahrbücher, Bd. 3, pp. 141–157..... 58, 61
- FORTIER, SAMUEL.
1903. Soil moisture in relation to crop yield. Montana Agricultural Experiment Station, 9th Annual Report, 1902, p. 107..... 15
- HEINRICH, REINHOLD.
1894. Ueber die Wassermengen, welche die Haferpflanze aus verschiedenen Nährstoff-Concentrationen während ihrer Vegetationszeit verbraucht. Zweiter Bericht über die Verhältnisse und Wirksamkeit der Landwirtschaftlichen Versuchs-Station, Rostock, pp. 170–174.....
- HELLRIEGEL, F. H.
1883. Verhältnis zwischen Produktion und Verdunstung.—Wie viel Wasser verbraucht eine Pflanze während der Erzeugung von einem Gramm Trockensubstanz durchschnittlich? In his Beiträge zu den Naturwissenschaftlichen Grundlagen des Ackerbaus. Braunschweig, pp. 622–664 13, 30, 33, 59, 61, 62, 74
- HÖHNEL, FRANZ, RITTER VON.
1881. Ueber den Wasserverbrauch der Holzgewächse mit Beziehung auf die meteorologischen Factoren. Forschungen auf dem Gebiete der Agrikultur-Physik, Bd. 4, pp. 435–445..... 10
- IL'ENKOV, P. A.
1865. Einige Versuche zur Bestimmung des Einflusses, welchen die Bodenfeuchtigkeit auf die Vegetation ausübt. Annalen der Chemie und Pharmacie, Bd. 136 (n. R., Bd. 60), Heft 2, p. 162..... 12
- KIESSELBACH, T. A.
1910. Transpiration experiments with the corn plant. Nebraska Agricultural Experiment Station, 23d Annual Report [1909], pp. 125–139, 2 figs..... 20, 50

- Cited in this
bulletin on
page—
- KIESSELBACH, T. A., and MONTGOMERY, E. G.
1911. The relation of climatic factors to the water used by the corn plant. Nebraska Agricultural Experiment Station, 24th Annual Report [1910], pp. 91-107, 2 figs. 21
- KING, F. H.
1889. Amount of water consumed by plants. Wisconsin Agricultural Experiment Station, 6th Annual Report [1888]/1889, pp. 191-192. ... 76
1892. The amount of water required to produce a pound of barley, oats and corn in Wisconsin. Wisconsin Agricultural Experiment Station, 8th Annual Report [1890]/1891, pp. 124-131, figs. 4. 76
1893. The amount of water required to produce a pound of dry matter in barley, oats, corn, clover, and peas in Wisconsin. Wisconsin Agricultural Experiment Station, 9th Annual Report [1891]/1892, pp. 94-100. ... 76
1894. The amount of water required to produce a pound of dry matter in Wisconsin. Wisconsin Agricultural Experiment Station, 10th Annual Report [1892]/1893, pp. 152-159, figs. 15. 34, 76
1895. The number of inches of water required for a ton of dry matter in Wisconsin. Wisconsin Agricultural Experiment Station, 11th Annual Report [1893]/1894, pp. 240-248. 57, 76
1905. Relative rates of evaporation at stations in four States from soil surfaces saturated by capillarity, and from corn. In his Investigations in soil management. U. S. Department of Agriculture, Bureau of Soils, Bulletin 26, pp. 192-198. 26, 60, 61
- KOLKUNOV, V.
1905. K Voprosu O V'rabotke V'nosliv'ykh K Zasukham Rass Kul'turn'ykh Rastenii. *Anatomo-Fiziologicheskiia i Biometricheskiia Issledovan'ia*. Kiev', 82 pp., 3 pls. (1)
- LAWES, J. B.
1850. Experimental investigation into the amount of water given off by plants during their growth; especially in relation to the fixation and source of their various constituents. *Journal, Horticultural Society, London*, v. 5, pp. 38-63, illus. 11, 31, 73
- LEATHER, J. W.
1910. Water requirements of crops in India. *Memoirs, Department of Agriculture, India. Chemical Series*, v. 1, no. 8, pp. 133-184, pls. 3-19. 20, 28, 30, 50, 57, 78
1911. Water requirements of crops in India.—II. *Memoirs, Department of Agriculture, India. Chemical Series*, v. 1, no. 10, pp. 205-281, illus. 28, 50, 78, 85
- LE CLERC, J. A., and BREAZEALE, J. F.
1911. Translocation of plant food and elaboration of organic plant material in wheat seedlings. U. S. Department of Agriculture, Bureau of Chemistry, Bulletin 138, p. 10. 10
- LIEBSCHER, GEORG.
1895. Untersuchungen über die Bestimmung des Düngerbedürfnisses der Ackerböden und Kulturpflanzen. *Journal für Landwirtschaft*, Bd. 43, Heft. 1/2, pp. 49-216. 26, 35
- MAERCKER, MAX.
1896. Über die Wirkung der Kalisalze auf Sandboden. *Arbeiten, Deutsche Landwirtschafts-Gesellschaft*, Heft 20, pp. 7-30. 13, 36

¹ The writers are indebted to Prof. T. A. Kieselbach for the reference to this paper, which contains data on the effect of the kind of plant and of soil-moisture content on the water requirement. It was received too late to be reviewed in this bulletin.

- Cited in this
bulletin on
page—
- MAERCKER, MAX**—Continued.
- 1896a. Versuche über die Beeinflussung des Wasserverbrauchs der Pflanzen durch die Kalirohsalze. Jahrbuch, Agrikultur-Chemische Versuchstation der Landwirtschaftskammer der Provinz Sachsen zu Halle a/S., 1895, pp. 15-16. 13, 36
- MARIÉ-DAVY, E. H.**
1874. Note sur la quantité d'eau consommée par le froment pendant sa croissance. Comptes Rendus, Académie des Sciences [Paris], t. 79, pp. 208-212. 33
1875. Évaporation du sol et des plantes. Annuaire Météorologique et Agricole de l'Observatoire, Montsouris, pp. 290-321. 25, 32
1876. Évaporation, transpiration. Annuaire Météorologique et Agricole de l'Observatoire, Montsouris, pp. 374-388. 25
- MONTGOMERY, E. G.**
1911. Correlation studies of corn. Nebraska Agricultural Experiment Station, 24th Annual Report [1910], pp. 108-159, illus. 67
1912. Methods of determining the water requirements of crops. Proceedings, American Society of Agronomy, v. 3, 1911, pp. 261-283, figs. 37-48, pls. 3-4. 11, 53
- and **KRESSELBACH, T. A.**
1912. Studies in water requirements of corn. Nebraska Agricultural Experiment Station, Bulletin 128, 15 pp. 64
- OHLMER, W.**
1908. Über den Einfluss der Düngung und der Bodenfeuchtigkeit bei gleichem Standraum auf die Anlage und Ausbildung der Ähre und die Ausbildung der Kolbenform beim Göttinger begrannten Squarehead-Winterweizen. Journal für Landwirtschaft, Bd. 56, Heft 2, pp. 153-171, pls. 7-10. 16, 44
- PFEIFFER, THEODOR; BLANCK, EDWIN; and FLÜGEL, M.**
1912. Wasser und Licht als Vegetationsfaktoren und ihre Beziehungen zum Gesetze vom Minimum. Die Landwirtschaftlichen Versuchstationen, Bd. 76, Heft 3/6, pp. 169-236. 22, 53, 63
- PREUL, FRANZ.**
1908. Untersuchungen über den Einfluss verschiedenen hohen Wassergehaltes des Bodens in den einzelnen Vegetationsstadien bei verschiedenem Bodenreichtum auf die Entwicklung der Sommerweizenpflanze, Göttingen. Inaugural Dissertation. Abstract in Journal für Landwirtschaft, Bd. 56, Heft 3, pp. 229-271. 18, 45
- SCHROEDER, M. R.**
1896. Razvitie i isparenie iachmeaâ pri razlichnoj vlazhnosti i pitatelnosti substrata. Izvîstîia Moskoskago sel Skokhozâistvennago Instituta, god 2, kniga 1 (Annales, Institut Agronomique, Moscou, ann. 2, livr. 1), pp. 188-226. 14, 37
- SEELHORST, CONRAD VON.**
1899. Über den Wasserverbrauch der Haferpflanze bei verschiedenem Wassergehalt und bei verschiedener Düngung des Bodens. Journal für Landwirtschaft, Bd. 47, Heft 4, pp. 369-378. 14, 37
1902. Vegetationskästen zum Studium des Wasserhaushaltes im Boden. Journal für Landwirtschaft, Bd. 50, pp. 277-280, pls. 9. 68
1906. Über den Wasserverbrauch von Roggen, Gerste, Weizen und Kartoffeln. I. Mitteilung. Journal für Landwirtschaft, Bd. 54, Heft 4, pp. 316-342, pls. 18. 27, 77
1908. Über den Wasserverbrauch von Lupinen im Herbst 1906 und von Kartoffeln, Sommergerste und Roggen im Sommer 1907 auf einem Sandboden. Journal für Landwirtschaft, Bd. 56, Heft 2, pp. 199-207. 77

Cited in this
bulletin on
page—

SEELHORST, CONRAD VON—Continued.

- 1908a. Über den Wasserverbrauch von Rüben, Roggen, und Gerste auf einem Lehmboden im Jahre 1907. *Journal für Landwirtschaft*, Bd. 56, Heft 2, pp. 195–198, pls. 12..... 70, 77
1909. Berichtigung zu dem Aufsatz: über den Wasserverbrauch von Lupinen im Herbst 1906 usw. im *Journal für Landwirtschaft* 1908, S. 199 u. ff. *Journal für Landwirtschaft*, Bd. 57, pp. 111–112.... 77
1910. Der Wasserverbrauch von Wiese und Weide. *Journal für Landwirtschaft*, Bd. 58, Heft 1, pp. 83–88..... 60, 61, 68, 72
- 1910a. Wasserverbrauch von Roggen auf Sandboden 1908/09. *Journal für Landwirtschaft*, Bd. 58, Heft 1, pp. 89–92..... 52, 56, 70
- and BÜNGER, J.
1907. Versuche mit Sommerweizen. *Journal für Landwirtschaft*, Bd. 55, Heft 3, pp. 246–260, pls. 4–5..... 16, 44, 70

SLËSKIN, P.

1908. K'voprosu o raskhodie vody sakharnoi soekloj. *Zhurnal Opytnoi Agronomu* (Russisches Journal für Experimentelle Landwirtschaft), t. 9, pp. 474–482..... 28

SORAUER, PAUL.

1880. Studien über Verdunstung. *Forschungen auf dem Gebiete der Agrikultur-Physik*, Bd. 3, pp. 351–490..... 62, 63, 65, 69
1883. Nachtrag zu den Studien über Verdunstung. *Forschungen auf dem Gebiete der Agrikultur-Physik*, Bd. 6, pp. 79–96..... 55, 74

WIDTZOE, J. A.

1909. Irrigation investigations. Factors influencing evaporation and transpiration. *Utah Agricultural Experiment Station, Bulletin* 105, 64 p., 7 figs., pp. 49, 52..... 19, 27, 29, 49, 78
1912. The production of dry matter with different quantities of irrigation water. *Utah Agricultural Experiment Station, Bulletin* 116, 64 pp., illus..... 84

WILFARTH, HERMANN, and WIMMER, G.

1902. Die Wirkung des Kaliums auf das Pflanzenleben nach Vegetationsversuchen mit Kartoffeln, Tabak, Buchweizen, Senf, Zichorien und Hafer. Berlin, 106 pp., illus. (Arbeiten, Deutsche Landwirtschafts-Gesellschaft, Heft 68)..... 39

WILMS, JOHANN.

1899. Einfluss des Wassergehalts und Nährstoffreichtums des Bodens auf die Lebensthätigkeit und Ausbildung der Kartoffelpflanze. *Journal für Landwirtschaft*, Bd. 47, Heft 3, pp. 251–292, pls. 3–5..... 15, 38

WIMMER, G.

1908. Nach welchen Gesetzen erfolgt die Kaliumaufnahme der Pflanzen aus dem Boden? Bearbeitet von H. Wilfarth, W. Krüger, H. Roemer, G. Wimmer, G. Geisthoff, O. Ringleben, J. Storck. Berlin, 169 p. (Arbeiten, Deutsche Landwirtschafts-Gesellschaft, Heft 143).... 16, 46, 66

WOLLNY, EWALD.

1877. Einfluss der Pflanzendecke und der Beschattung auf den Wassergehalt des Bodens. *In his* Der Einfluss der Pflanzendecke und Beschattung auf die physikalischen Eigenschaften und die Fruchtbarkeit des Bodens. Berlin, pp. 105–135..... 73

WOODWARD, JOHN.

1699. Some thoughts and experiments concerning vegetation. *Philosophical Transactions*, [Royal Society, London], v. 21, no. 253, pp. 193–227..... 11, 54, 72

